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Automobile Starting and Lighting

A Non-Technical Explanation of the Construction, Upkeep and Principles of Operation of the Electrical Equipment of Automobiles

By
HAROLD P. MANLY

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PREFACE

"Automobile Starting and Lighting" has been written to give a working knowledge of the construction and action of the various parts of electrical equipment, together with a necessary understanding of the principles that govern their operation. The necessity for such a work is evident in that more than ninety-eight per cent of all cars now produced are electrically started and lighted.

Detailed explanation is given of all types of construction at present in use or that have been adopted in former installations, thus allowing the user to apply the information to future developments as well as to all those now found. By treating the subject according to the several units entering into all constructions, the entire field has been covered without the necessity of too brief explanation or such repetition as would be called for by other methods. The particular applications found in the well-known makes of apparatus have been outlined in one portion of the book.

The attention of the practically inclined user is called to the chapter on storage batteries, to the chapter describing the action of regulating and cut-out devices, to the chapter on Troubles and Remedies, and to the last chapter, in which has been explained the meaning of two hundred of the words and terms generally used in starting, lighting and ignition work, and in the application of electrical science found in this field.

THE AUTHOR.

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AUTOMOBILE STARTING AND LIGHTING

CHAPTER I

ELECTRIC LIGHTING AND ENGINE-STARTING EQUIPMENT

The fundamental principles employed in all of the various makes of automobile electrical equipment are the same regardless of the particular application chosen by the designers and builders. All systems must provide parts which accomplish certain results essential to the operation of the system as a whole.

In some cases a single part may perform two or more functions, in other cases separate parts will be provided for each function, while in still other cases some of the parts may apparently be absent. Nevertheless, every successful electrical installation must cause the same actions to take place, and parts must be provided that will bring about the effects necessary for continued operation.

It is first of all necessary to cause a flow of electric current, and this is done by the dynamo, or generator, operated by the gasoline engine. A certain amount of power is required to run the dynamo, and this power is taken through gears, chains or belts between the engine and dynamo or by mounting the dynamo on the engine crankshaft. The dynamo may be defined as the mechanism that changes the mechanical power received from the engine into electric current.

It is evident that the engine cannot always be running when current is required, inasmuch as it is necessary to light the lamps under this condition and to start the engine from rest. It is, therefore, necessary to accumulate and store the surplus energy that is produced during the time the engine runs under its own power, and this is accomplished by the storage battery which is a vital part of every electrical equipment.

Having a source of current and a means of retaining a part of the energy until it is needed, it remains to attach the parts that consume current in lighting, starting, ignition and control of the automobile. These parts include the various lamps, an electric motor for cranking the engine, and in many cases the parts for ignition, gear shifting, carburetor heating and the many electrical accessories which are found in use.

Thus, the four essentials of the electric system are dynamo, battery, lights and starting motor. In order to allow the operator of the car to use these parts, and to cause them to perform their duties properly and without danger to themselves, certain controlling and regulating devices are necessary.

For convenience in further explanation, the electrical apparatus of the car will be divided into three principal parts (Figure 1), the charging system, the lighting system, and the starting system. The charging system will include the dynamo, the battery, and all the parts required for their operation and use. The lighting system will include the lamps and their wiring, also the parts needed for their control. The starting system will include the starting motor, the starting switch and the necessary wiring.

In order to prevent confusion, the following usages have been adopted and will be followed throughout this work. While both words refer to the same instrument, the word "dynamo" will be used in preference to "generator" whenever the dynamo-electric machine is used to cause a flow of current. The word "motor" will refer to the electric starting motor and not to the automobile engine. The combination of dynamo and motor in one unit will be called a "motor-dynamo." For an explanation of the meaning of electrical words and terms used in starting and lighting, see Chapter IX.

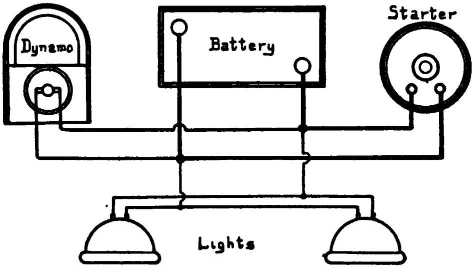


Figure 1.—Connections for Charging, Lighting and Starting Systems.

CHARGING SYSTEM

Dynamo.—The dynamo consists of a revolving element, operating in connection with a stationary element. The rotation of one of these parts with reference to the other generates a flow of electric current in one of them, called the armature, and the current then passes from the armature out of the dynamo to the battery and other electrical parts. The second element is called the field magnet, and provides the necessary magnetism.

The usual construction, Figure 2, makes the armature the rotating element, and the most common form of armature is built by mounting on a shaft a sufficient number of soft iron discs to make a cylinder, or else a cylindrical piece of soft iron is used in one piece. This part is called the armature core. Running lengthwise of the core are a number of grooves or slots, these slots being of sufficient width and depth to allow a quantity of insulated wire to be wound on the core and in the slots. The coils formed by this wire are called the armature windings, and it is in these windings that the current flow is first generated.

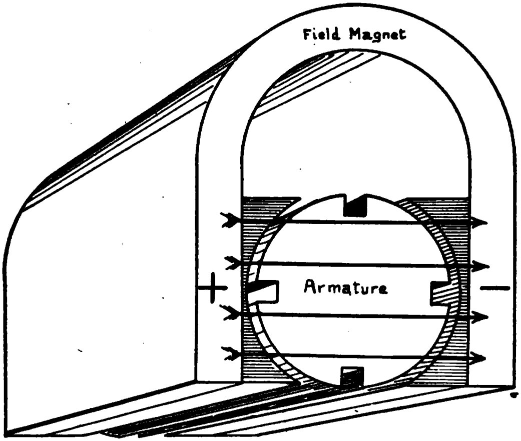


Figure 2.—Lines of Force Passing Through Dynamo Armature.

Various forms are adopted for the field magnet, the shape depending on the size and mounting that will be required for the particular machine being designed. If a single magnet is used, that is, a magnet having but two ends, these ends are placed in such a position that they are at opposite sides of the armature core and the magnetism that passes from one end to the other must therefore pass across and through the armature core. The ends of the magnet are curved to bring them close to the armature, and the cylindrical passage between them, in which the armature rotates, is called the armature tunnel.

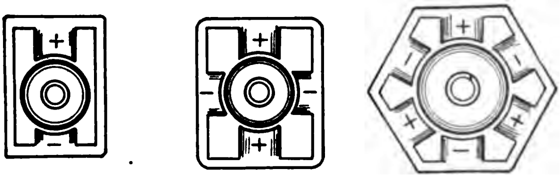


Figure 3.—Two-Pole, Four-Pole and Six-Pole Electric Machines.

Should the magnets be formed with four or six ends, as is often the case, the ends are placed so that they form pairs on opposite sides of the armature and are directly across from each other. The machine is then called a four-pole or six-pole dynamo (Figure 3), depending on whether there are four or six magnet ends placed around the armature.

The magnets that produce the field are made from soft iron, and the soft iron, called the magnet core, is surrounded with a coil of insulated wire. When a flow of current passes through this wire, the soft iron becomes a magnet, this type being known as an electro-magnet, as differing from a permanent magnet, which is made from hardened steel. The coil of wire around the magnet core is called the field winding, and the current that passes through this winding to make the core magnetic is secured by taking a part of the current generated in the armature.

As the armature rotates between the field magnet poles, the current caused to flow through each one of the armature coils travels in one direction through the wire while the armature and coil make a half revolution, and then, on the next half revolution, the current is caused to pass in the opposite direction through the winding. A current that reverses its direction of flow in this way is called an alternating current, and is not suitable for battery charging purposes because of the fact that the reversal of flow would take out as much current as it would put into the battery.

In order to change this alternating current into a flow that always travels through a wire in one direction, the commutator is used. The current having a continuous direction of travel is called direct current, and is the only form suitable for battery charging.

The commutator consists of a number of copper bars arranged in a circle around one end of the armature shaft and fastened to the shaft so that they turn with it. These bars are separated from each other by some material that will not carry electric current; in other words, are insulated from each other. Each pair of copper bars is fastened to an armature winding coil that rests in one pair of slots, and the other bars are fastened to the other coils of wire that form the armature. This construction makes it necessary to have double the number of commutator bars that there are armature windings, each pair of bars forming the two ends of one coil on the armature.

Because of the fact that a flow of current is generated in an armature coil while it is passing across one of the magnet poles, one electrical impulse is generated in each direction by a two-pole machine, as already mentioned. One complete revolution of the armature, Figures 4 and 5, will cause both sides of the coil, which means the whole coil, to pass first across the end of one pole of the magnet, then across the end of the other pole. This action will send an impulse to the commutator bars first in one direction, then in the other.

Two brushes, made from some material that carries electricity with ease, are placed so that they rest against the surface of the commutator bars and at opposite points on the commutator surface. The brushes are therefore in contact with opposite bars at the same time, and with the two ends of the armature coil. Any flow of electric current generated in the armature winding will pass into these brushes.

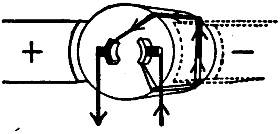


Figure 4.—Armature Coil Passing Negative Pole.

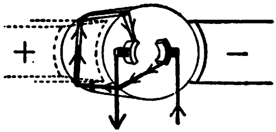


Figure 5.—Armature Coil Passing Positive Pole.

Now, bearing in mind the fact that the current reverses each half revolution, and also the fact that the commutator bar in contact with one brush at one position will have changed to the other brush when a half revolution has been made, it will be seen that the current will always be given to the brushes in the same direction. This is true because, while the direction of flow has reversed, the position of the commutator bars with reference to the brushes has also reversed, and as far as the brushes are concerned, the flow continues in the same way.

Should the dynamo be a four- or six-pole unit, the reversal of current will take place four or six times in a revolution, and it is customary to provide four or six brushes, half of the total number in any case taking the current flowing in one direction, while the remaining brushes take the current flowing in the opposite direction.

From the brushes, wires and connections lead to the battery, lamps and other current-consuming devices, and in most cases to the field magnet windings also. The method of leading part of the generated current around the field magnets is one of the important considerations in dynamo design, and will be considered in the next chapter.

Current Measurement.—Electricity is not a material thing and cannot be measured according to the usual standards of weight or dimensions. It can only be measured by its effects that are produced in various ways. The two principal values of electricity that are generally useful in this work are pressure, expressed in volts, and rate of flow, expressed in amperes.

Electricity passes through conductors, such as wires and all other metallic things, because of the pressure, or voltage, and the flow sent through the conductor by this pressure is measured as amperage. The actual flow depends on the pressure being exerted and the resistance of the wire or other conductor to the passage of the current. If the voltage remains at a constant point, the flow sent through the conductor will be in proportion to the resistance; more flow passing as the resistance becomes less, and less flow passing as the resistance increases. Should the resistance remain the same, an increase of voltage will cause an increased flow, while a decrease in voltage will allow the flow to become less.

The resistance of a conductor depends on its size or cross section, the resistance becoming less as the size increases. Resistance also depends on the length of the conductor through which the electricity must pass, the resistance increasing in direct proportion to increase in length. Other things affecting the resistance are the material of the conductor, some metals being much better conductors than others, and also the temperature, high temperatures generally causing the resistance to increase.

Electricity	Unit of	Water
Volt	Pressure	Pounds to Square Inch
Ampere	Flow	Gallons per Minute
Watt	Power	Horsepower

Figure 6.—Electrical and Hydraulic Units Compared.

It should be clearly understood that voltage measures only the pressure and does not indicate any particular quantity or volume of electricity. Voltage corresponds to pounds to the square inch in hydraulic work and similarly indicates only the pressure that is available when a flow takes place.

On the other hand, amperage measures only the rate at which the current passes a given point, and unless the amount of time during which this flow continues is known, the amperage does not indicate the quantity of current that has passed. Amperage may be compared to the measurement of water flow in gallons per minute, when, unless the number of minutes is known, the quantity of water cannot be calculated. (See Figure 6.)

The useful work that electric current can perform depends on the pressure, or voltage, available, and also on the rate of flow, or amperage. A current of one ampere having a pressure of ten volts will do exactly the same work that a current of ten amperes at one volt will do. Any other combination of volts and amperes which multiplied together will give ten will likewise do an equal amount of work. The work that a current will do is measured in watts, one watt being the power furnished by a flow of one ampere at a pressure of one volt. Any number of amperes multiplied by the number of volts pressure will give the number of watts. Thus, a lamp through which a current of two amperes is flowing under a pressure of six volts is consuming twelve watts in electrical power. An electric starting motor through which one hundred amperes is flowing at six volts is consuming six hundred watts in electrical power. Seven hundred and forty-six watts in electrical power is the equal of one mechanical horsepower.

Before leaving the subject of electrical measurements, it should be explained that the resistance of any material, such as a conductor, is measured in ohms, and the relation between the arbitrary units, volts, ohms and amperes, may be explained as follows:

A volt is the pressure required to force one ampere flow against a resistance of one ohm.

An ampere is the flow caused by an electrical pressure of one volt acting against a resistance of one ohm.

An ohm is the resistance that will allow a flow of one ampere to pass under a pressure of one volt.

The practical expression of "Ohm's Law," one of the most useful rules in electrical work, is as follows:

The voltage is found by multiplying the amperage by the resistance.

The amperage is found by dividing the voltage by the resistance.

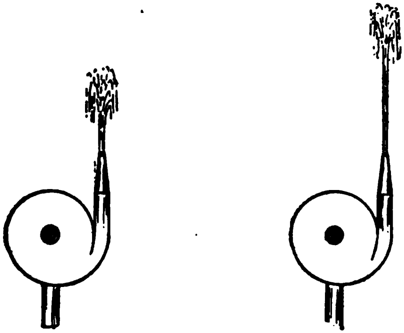


Figure 7.—Relative Pump Flow at Low and High Speed.

The resistance is found by dividing the voltage by the amperage.

It will thus be seen that, knowing any two of the above values, the third may easily be found.

Dynamo Regulation.—It is often of assistance in understanding electrical action to compare it to the action of water. The dynamo may be compared to a water pump, and the flow of electric current from the dynamo may be compared to the flow of water from a pump. In either case, the pressure increases with increase of speed and the higher pressure causes a greater flow. As the speed of a water pump increases, the water pressure in pounds to the square inch increases, and the flow in gallons per minute then increases. (See Figure 7.) With increase of dynamo speed, the pressure, measured in volts, and the flow, measured in amperes, both increase in proportion. Just as uncontrolled increase in water pressure and flow might cause damage, so will unchecked increase in voltage and amperage result in damage to the electrical parts. Excessive amperage, or flow of current, would damage the storage battery and the dynamo itself, while an undue rise in voltage, or pressure, will damage dynamo, battery and lamps.

In order to prevent such damage, various methods have been adopted for controlling the dynamo output. A suitable operating voltage is selected when the equipment is designed, this voltage usually being six, eight, twelve or eighteen, and the design is carried out in such a way that this voltage is maintained at all times without considerable increase or decrease.

The flow allowed from the dynamo to the storage battery should be proportioned to the size of the battery, and the size of the battery is in turn suited to the current consumption of the car's equipment. Control of the dynamo output, that is, its voltage and amperage, will be designated by the word "regulation."

Cut-Out.—Following the analogy between electricity and water, compare the storage battery to a tank into which a pump, the dynamo, forces water from a lower level. It will be understood that the pressure at the pump must be higher than the pressure at the tank in order that a flow may take place from pump to tank. Similarly, the voltage of the dynamo must be greater than the voltage of the battery in order that current may flow from dynamo to battery. Just as long as the dynamo voltage remains above that of the battery, the flow will continue and the battery will receive a charge. When, however, the dynamo voltage falls below that of the battery, as it will when the dynamo is idle or running at very low speed, then the battery pressure or voltage will be greater than that of the dynamo, and if the two units remain connected through the wiring, there will be a reverse flow from battery to dynamo. This reverse flow, if allowed to continue, will rapidly withdraw the current from the battery. To prevent such a useless and damaging battery discharge, one of several methods is adopted whereby the dynamo is disconnected from the battery when the dynamo voltage is too low to cause a flow of current to the battery. One method makes use of an automatic switch that operates according to the voltage of the dynamo, this switch acting to disconnect the dynamo and battery when the dynamo voltage falls below a certain limit and to establish the connection again when the voltage rises to a point that allows of battery charging. This switch may operate electrically or by centrifugal force, either type being called a reverse current cut-out, or simply a cut-out. A large majority of all cars use the electromagnetic form.

The dynamo is not always disconnected automatically in one of the ways described, but may be disconnected by a switch operated by the person driving the car. This type of switch is interconnected with the ignition or starting switch in such a way that the dynamo and battery will be disconnected whenever the gasoline engine is idle, or running at low speeds. The dynamo speed with the engine running at the usual rate is sufficient to produce a charging voltage.

This form of switch is often called a hand-operated cut-out.

In many cases the automatic cut-out is combined, or is carried in the same case, with the device for regulating the dynamo output. In such a design the combination is called a "controller." This practice is often followed when the regulating device is a separate instrument, complete in itself, but apart from the dynamo. Many systems are designed in such a way that regulation of output is accomplished within the dynamo and by parts of the dynamo. This internal method is called "inherent regulation."

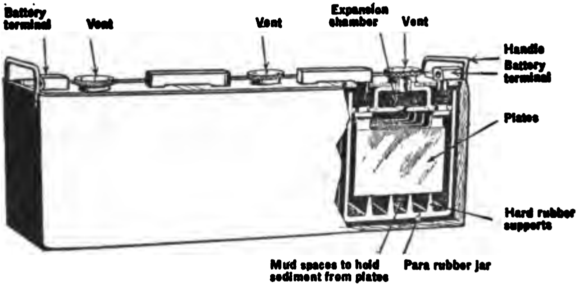


Figure 8.—Section Showing Parts of Storage Battery.

Various locations are used for the controller or the separate cut-out. These units may be carried inside of the dynamo case or mounted on the outside of the case. They may be on the engine side or the driver's side of the dashboard. They may be placed under the driver's seat or, in some cases, under the floor boards. Other designs locate these units with the starting switch, lighting switch or other instruments.

Battery.—Although the battery, Figure 8, has been classed as a part of the charging system, it also forms an essential part of both lighting and starting systems because of the fact that it furnishes the current with which these parts operate. Being a part of each of the three principal divisions makes the storage battery the center of the whole electrical equipment and of the greatest importance.

With the exception of the battery, all units of the starting and lighting equipment operate mechanically or electrically. The battery is electro-chemical in action, and does not store electricity in the form of current. Electric current generated by the dynamo flows through the battery and in doing so causes certain chemical changes to take place in the elements of which the battery is composed. This action is known as "charging," and after the battery has been charged, the chemical composition of the elements differs from what it originally was.

After the battery has been charged, it is capable of causing a flow of current through conductors attached to it. In causing this flow the battery elements again go through a chemical change. When the action within the battery has progressed to a point at which the elements have returned to their discharged condition, the battery can cause no further flow of current. A new flow sent through the battery by the dynamo will restore the battery elements to their charged state, and connecting the outside circuits to the battery will allow the discharge which ends with a return to the chemical condition called "discharged."

This fundamental difference between the battery, which is a chemical unit, and all others, which are electrical or mechanical, causes a large part of the trouble that results from lack of care on the part of the user.

Indicating Devices.—It is desirable for many reasons to know whether or not the battery is being charged, and also to know the rate of charge or discharge at any time. It is not possible to measure directly the amount of current flow that a battery is capable of delivering, starting with a given time; that is to say, the "charge" remaining in the battery cannot be measured. It is, however, possible to make tests which will give a close approximation of the condition of charge by testing the liquid contained in the battery. A less reliable indication is the voltage of the battery while undergoing charge. The voltage rises and falls with increase or decrease of current flow that may still be secured from the battery, and this voltage may be measured by an instrument called a voltmeter when electrically connected to the battery.

Four methods are in use which show directly when current is being sent from the dynamo to the battery or lamps. The most satisfactory method, from the standpoint of accurate information on the exact conditions obtaining at any given time, is by the use of an ammeter. This instrument, placed in the electrical circuit, shows the direction of flow and also the amperage passing. It may be so placed that the flow either into or out of the battery is indicated at the time of reading.

Other instruments, called "indicators," are used for purposes similar to those of the ammeter, the indicator showing whether the battery is being charged, discharged or held without flow either way.

The exact flow in amperes is not measured by an indicator.

A third method consists of employing a visible marker or target attached to the automatic cut-out switch, or to an electromagnet in the charging circuit, the target being fitted in such a way that the driver can tell whether or not the dynamo is delivering a flow of current. Such a target does not indicate whether the current flow is passing into the battery or to the lamps, and this method is therefore of value only for checking the dynamo action.

A fourth method makes use of a lamp called a "pilot lamp," this lamp lighting whenever the dynamo is connected to the charging circuit by the cut-out, and remaining dark whenever the cut-out is open and the dynamo disconnected from the circuits. The pilot performs the same function as the target mentioned in the preceding paragraph.

LIGHTING SYSTEM

Lamp Bulbs.—The incandescent lamps used in automobile lighting are formed by inserting a strand or filament of tungsten or carbon in a glass bulb from which all but a small percentage of the air has been exhausted. Another type of bulb replaces the air with nitrogen gas, this form of bulb giving a slightly greater volume of light for the current consumed than the vacuum type.

All bulbs are rated according to the voltage with which they are designed to operate and by the number of amperes or watts used when the proper voltage is present. Rating is also given in the candlepower developed when the bulb is consuming the rated amperage at the normal voltage.

The candlepowers in use vary from one to forty, and the voltages from three and one-half to twenty-one, according to the equipment of the car. The candlepower and voltage do not necessarily bear a definite relation to the size of the glass bulb enclosing the filament. Various standard sizes of bulb are in use, and with a lamp case and reflector designed or focused for a certain size, the use of this size should be adhered to unless the focusing arrangements allow of a proper setting for a different bulb.

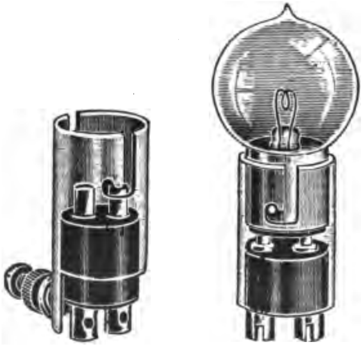


Figure 9.—Bayonet or "Ediswan" Lamp Base Construction.

Three forms of bulb base and socket are in use. The type most commonly found is the "Ediswan" or "bayonet" type (Figure 9). This base is cylindrical in form and has two small pins attached to opposite sides of the round portion of the base. The bulb fits loosely into a hollow cylindrical socket, and the pins on the base slide down into lengthwise slots cut in the sides of the socket. At the bottom of the socket these slots turn at right angles and extend for a short distance around the socket, ending in a notch designed to catch the pins on the base. Springs placed in the bottom of the socket hold the pins on the base tight in the notches. Current is carried from the socket into the bulb through contacts formed by springs or plungers. These plungers are depressed when the bulb is put into the socket and form the conductors in most cases.

In the "double contact" type of Ediswan base and socket two plungers are provided which make contact with two metallic points on the bottom of the base. One contact carries one side of the electric circuit, while the remaining contact carries the other side. The "single contact" base has but one plunger and but one point on the bottom of the base. This contact carries one side of the circuit, while the other side of the circuit is carried through the metal that forms the socket cylinder and the housing for the bulb base.

A third type, of the screw form, is seldom met with except in interior body wiring. The large size of screw base is called "candelabra," while a smaller size is called "miniature."

Wiring and Switches.—In making the necessary connections on the car, the dynamo is connected to the battery for charging purposes. All of the remaining principal divisions are also connected to the battery so that they may secure their supply of current. This means that all of the current-consuming units are connected to the dynamo and battery, the interconnection being made at the battery terminals or battery wires. Current from the dynamo may therefore pass into the battery or may go to the lamps; the flow being into the battery with all lamps off or with such a number of lamps lighted that do not require all of the current being generated by the dynamo. If sufficient lamps are lighted to take all of the current generated by the dynamo, none will be left to pass into the battery. If so many lamps are lighted that they take more current than the dynamo generates, the battery will be drawn upon for the balance required. If the lamps are lighted with the dynamo idle, all of the current required will be taken from the battery. (See Figure 10.)

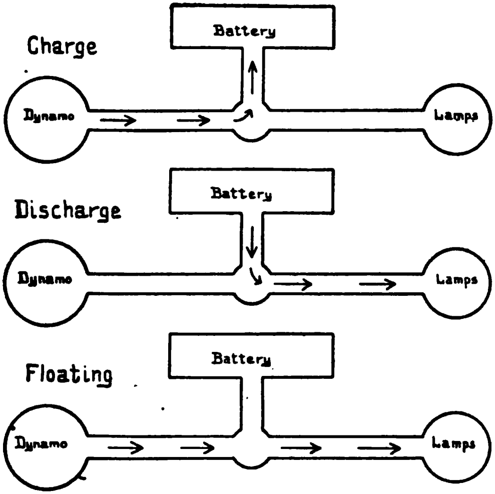


Figure 10.—Current Flow Between Battery, Dynamo and Lamps. Top: Dynamo Running, Lamps Off. Center: Dynamo Idle, Lamps On. Bottom: Dynamo Running, Lamps On.

Three principal methods of lamp wiring are in use; the one-wire or ground-return method, the two-wire method, and the three-wire method.

The two-wire was used first. By this method each side of each lamp is connected directly to the battery through conductors to form a complete circuit. That is, one side of the lamp is connected to the positive side of the battery while the remaining side of the lamp is connected to the negative side of the battery, both sides of the circuits being completed through copper wire and the necessary switches and fittings.

The one-wire method is a more recent development, but has gained rapidly in number of users since its first introduction. This method utilizes the frame and other metal parts of the car to complete one side of the circuit, this being possible because of the fact that all metals are excellent conductors. Each wire and each circuit that is connected to the frame or metal parts is said to be "grounded," and the metal parts are referred to as "ground."

The circuits for a one-wire, or ground-return, system are completed as follows: From one side of the battery, either the positive or negative terminal, a connection is made to the frame of the car, thus grounding one side of all circuits. From the remaining battery terminal wires are run to the lighting switches, to the dynamo and to the other electrical units that must have connection with the battery. These wires from the ungrounded side of the battery are led to one side of each of the lamps and other units, and the remaining side of each of these units is then connected to the frame of the car or to other metal parts in contact with the frame. These grounding connections from the electrical units often require that short lengths of wire be used, but the length of wire used is less by a large percentage than the length required with the two-wire system.

Each system of wiring has certain advantages of its own, also disadvantages. Each system has its advocates, and the arguments put forth are many for each side of the question. The principal advantage claimed for the single-wire system is the comparative ease of insulating the parts. The size of all parts is necessarily small, and it is apparent that when the whole available space can be used for insulating one conductor, the problem is simpler. The principal advantage of the two-wire system is claimed to be the comparatively less danger of short circuits because of the fact that it is necessary to break the insulation on both positive and negative sides of the circuit before an improper flow can take place from one side of the battery to the other.

The three-wire system may be an adaptation of either the one- or two-wire system. The three-wire method makes it possible to use lamps of two different voltages on the same car and from one battery. The battery is divided into two parts of such size that one part gives one voltage desired, while the whole battery, or the remaining part, gives another voltage higher than the first. One of the three wires is called the "neutral" wire, and if a connection is made between this neutral wire and one of the others, one of the voltages is secured, while a connection between the neutral wire and the third wire will give the second voltage. Another three-wire system will give the same voltage between the neutral wire and either of the others, while a higher voltage may be obtained by making a connection between the two outside wires, omitting the neutral wire altogether.

The advantage of a three-wire system is in the smaller amperage that must be carried through the wires to do an equal amount of work. It has been explained that electrical work is measured in watts and that watts are found by multiplying the voltage by the amperage. It will be realized that with a given amount of work to be done, the wattage will remain the same, and with the higher voltage the amperage may be reduced in proportion. The size of wire required depends on the amperage to be carried and not on the voltage, therefore a reduction in amperage allows of economy in wire.

The wiring system of the car includes the units that are necessary in making secure connections of low resistance, the switches that give the driver control of the system, fuses and circuit breakers for protection against excessive flow, and the conduits and other carriers for the conductors. While some parts of the wiring may be used only for purposes of charging, of lighting or of starting, other wires may be used for two or for all of these functions.

STARTING SYSTEM

The electric starting system makes use of an electric motor that is connected to the battery through the starting wires and the starting switch. The construction of the motor is similar to that of the dynamo already described. It comprises an armature with its commutator and brushes, all mounted on a shaft; also field magnets and field windings. The difference between a dynamo and motor does not lie in their construction, but in the fact that power is converted into electric current by the dynamo, while the motor converts electric current into power.

When current is led to the motor, it magnetizes the field magnets and also magnetizes the armature. The reaction between the two magnetic fields causes the armature to revolve within the field and power to be produced.

The construction of the type of motor usually employed is somewhat simpler and more rugged than that of the dynamo, the windings being much heavier and a lesser length of wire being used in their construction. The connections and current carrying parts in the motor must be of very low resistance, which means well made. This is true because the amperage to be carried is very large and the pressure or voltage is comparatively low. A slight increase in the resistance at any joint will offer such great opposition to the low voltage that the flow will not be sufficient to handle the work properly. When it is realized that the amperage passing through an ordinary starting motor, if supplied at the voltage used in ordinary power circuits, would develop about forty-five actual horsepower, the necessity for careful handling to avoid loss will be appreciated.

The same rules apply to the starting switch and to the wiring. They must have large current carrying capacity and must be securely and carefully connected so that the heavy currents may be handled without great loss. Fortunately, these parts are simple and of comparatively large size.

Because of the similarity of construction of dynamos and motors the two units are often replaced with a single machine having but one armature and one set of field magnets. The armature may have one set of windings and one commutator on its core or may have two sets of windings and two separate commutators and sets of brushes. The fields may likewise have one set of windings or more than one set, some being used for generating purposes only while the others may come into use only when the machine is acting as a starting motor. This combination is called a "motor-dynamo'' and, while having certain disadvantages electrically, has the undoubted advantage of mechanical simplicity and comparative ease of mounting to offset its slightly lower efficiency in the use and generation of current.

CHAPTER II

LIGHTING DYNAMOS AND STARTING MOTORS

The size and capacity of a dynamo for a certain installation depends on the number of lamps to be used and their candlepower, also on the amount of power required to start the gasoline engine. The useful work that may be accomplished with the current supplied from the dynamo depends on the voltage and amperage, that is, on the number of watts. The output of dynamos is measured in amperage and depends to a certain extent on the speed at which the armature is turning. The exact ratio of output to speed depends on the type of regulation that has been adopted for the dynamo. Some forms of regulation allow the amperage to rise rapidly to its maximum value and then to remain practically constant, without increase or decrease, at all higher speeds. Other forms of regulation provide for a gradual rise from zero to maximum and allow the amperage to increase with the speed over practically the whole range. Still other regulating methods provide for a comparatively quick rise to the maximum amperage and then cause the amperage to decrease with greater dynamo speed. In some cases the amperage delivered by the dynamo is determined by the voltage of the battery, the amperage becoming less and less as the battery voltage increases with the approach to a fully charged condition. The practice is often followed of automatically increasing the dynamo output when any or all of the lamps are turned on, this action serving to compensate for the additional load imposed by the lamps.

It will be seen from the foregoing statements that no general conclusions can be drawn and no general rules given by which it may be determined whether or not a dynamo is giving its proper amperage. If the characteristics of the particular machine being considered are known, the work is made easy; but in the absence of this information it is generally necessary to make additional tests on other units, such as the battery. These tests will show whether the dynamo is doing its proper work provided everything else is known to be in condition for efficient use. There is but one rule that may be useful in the superficial checking of the dynamo operation; this rule being that an ammeter attached to the battery should show a slight charge with all lamps turned on and the engine running between fifteen and eighteen miles per hour car speed.

The rule as stated will almost always hold good, and if the ammeter should show a discharge under those conditions it is safe to assume that the dynamo is not giving sufficient output or else that some trouble exists between dynamo and battery that is preventing the proper charge from entering the battery. It is of course assumed that the lighting system and wiring is in good order while making the test.

An error is often made in the application of this rule, it being stated that the dynamo output at a car speed of fifteen miles per hour should be equal to the discharge from the battery with all lamps turned on. The two statements are not equivalent because of the fact that so many important systems of regulation increase the dynamo output with the lamps turned on, but allow it to fall to a low value with the engine running and the lamps turned off.

If it is desired to test the condition of the dynamo only, the test should be made at the dynamo itself. If it is desired to test the actual charging conditions on the car, the test should be made at the battery, because it is the charge that enters the battery that is of importance. The dynamo might be doing all that could be expected of it, but the current generated would be of no use unless it was reaching the battery, lamps, etc.

In testing the output of a dynamo, an ammeter should be inserted between one of the dynamo terminals that carries charging current and a wire end removed from this same terminal. A test made between the positive and negative terminals of the dynamo would not give the same results under ordinary conditions. With a majority of the dynamos in use, a storage battery, or its equivalent in resistance, must be in the dynamo circuit while making the test, because the output of the dynamo depends on its having to make an effort to force the current through the battery. Additional information on making such tests will be given, but the foregoing precautions should always be observed and were mentioned thus early because of the misunderstanding that so often exists.

FIELDS AND FIELD WINDINGS

A large percentage of all dynamos in use at the present time use electromagnetic fields, that is, field magnets of soft iron which are magnetized by current that flows through coils of wire placed around the field magnet cores. Dynamos have been built that use field magnets made of hardened steel, which when once magnetized will retain their magnetic properties over long periods of time in ordinary use. Others have been built with these permanent magnets in combination with electromagnets. All forms of dynamos using permanent magnets are comparatively rare and their use is decreasing.

As previously mentioned, dynamo field magnets may be built so that the armature rotates between a single pair of magnet ends or poles, or else the construction may allow for four, six, or more magnet poles. A two-pole machine may have coils of wire on each of the poles or it may be built with the coils placed on only one pole. In the latter case the unwound pole is called a consequent pole and is of opposite polarity from the wound pole; that is, if the wound pole is positive, the unwound one will be negative, and if the wound pole is negative, the unwound one will be positive. Four-pole machines generally have but two of the poles wound, these two being of the same polarity, both positive or both negative. On each side of the armature and half way between the wound poles will be two consequent or unwound poles of polarity opposite to the wound poles.

Two-pole machines have two brushes to collect the current from the armature, one positive brush and one negative brush. Four-pole and six-pole machines may have four or six brushes respectively, or may be constructed in such a way that but two brushes are required, regardless of the number of poles.

As previously mentioned, the method of connecting the field windings with the armature brushes is of great importance in design, and in fact forms the principal difference between dynamos of different types. It will be realized from the explanation of the poles already made, that the field windings may be on one or more than one of the pole pieces, Figure 11. The number of windings, or the number of poles that are wound, does not affect the principles used in connecting the windings; the variation in the number of parts or poles simply means that the windings are divided into several parts or are all on one pole piece. This understanding will make it unnecessary to refer to the number of poles in the following explanation of the various methods of winding.

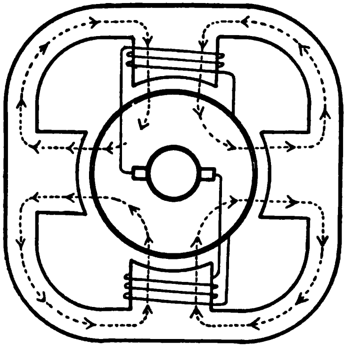


Figure 11.—Flow of Magnetism in Field of a Four-Pole Machine.

Figure 12 shows the field windings and their connections for a plain "shunt wound" dynamo. The right-hand brush is positive and the current generated in the armature passes from this brush through the heavy wires to the outside circuits, returning through the other outside wire to the left-hand negative brush. It will be noted that one end of the coil of wire around the field magnet is attached to the positive brush while the other end of this field coil is attached to the negative brush. This connection allows a part of the current from the armature to pass through the field magnet winding and thus magnetize the iron core. The direction of flow around the magnet in this case causes the upper pole to become positive and the lower one is therefore a consequent negative pole without a winding. When two circuits, such as the field circuit and the outside circuit, are so connected to a source of current that a part of the flow passes through each circuit, the circuits are said to be in shunt with each other, and either one is called a shunt with reference to the other. The field circuit in Figure 12 is therefore a shunt of the outside circuit and this dynamo is said to be shunt wound. This form of winding, with several modifications, is by far the commonest of all those in use for dynamos.

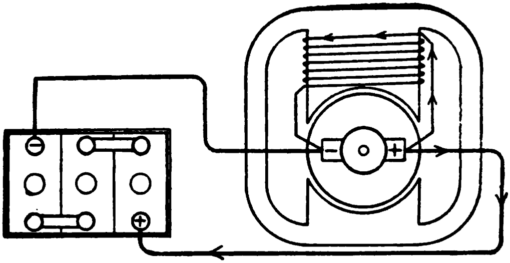


Figure 12.—Shunt Field Winding.

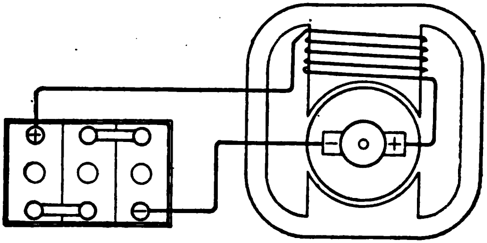


Figure 13.—Series Field Winding.

Figure 13 shows the connections that form a series winding. This method of connection is not used for dynamos unless in combination with a shunt, but is shown because of its relation to this question. This form places the armature and the field winding in the same circuit and so that all of the current passing into or out of the armature must also pass through the field winding. Any circuit in which all of the current that passes through any one part must also pass through each and every other part is said to be a series circuit, and inasmuch as the method illustrated in Figure 13 conforms to this rule the dynamo would in this case be series wound. As stated, this form is never used for automobile lighting dynamos.

For dynamo work, the series winding is useful when combined with the shunt in either of two forms. One combination is called "compound wound," while the other is called a "reversed series" winding. In either case the series winding is used to assist in dynamo output regulation.

The direction in which the field current passes through the wire composing the field winding determines the polarity of the magnet ends. When looking at the end of an electromagnet, should the current be flowing around through the magnet winding in the direction that the hands of a clock travel, then the end being looked at is the negative pole; while, if the current travels in an anti-clockwise direction, the end being observed is positive. The magnetic strength of the field is determined by the number of turns of wire around the pole and the amperage passing through the wire. The number of turns of wire multiplied by the number of amperes flowing gives the number of "ampere-turns," and the strength of magnets is determined by the ampere-turns. It will be seen that the strength of the field in any dynamo depends on the number of ampere-turns acting on the metal of the field magnets, the strength becoming greater with increase of ampere-turns. The output of the dynamo depends on the strength of the field and the speed of rotation of the armature, therefore, if the speed remains constant the voltage and amperage will depend directly on the field strength, or on the number of ampere-turns acting to produce the magnetic field.

The connections used in making a compound wound dynamo are shown in Figure 14. It will be seen that the shunt winding is exactly similar to that shown in Figure 12, while the series field winding has been added just as it is placed on the magnet of the dynamo shown in Figure 13. It should also be noted that the flow of current through both shunt and series field coils is in the same direction, therefore they both tend to produce the same polarity in the field magnets and the series winding adds its effect to that of the shunt coil and in the same direction. The greater the flow through the series winding in the compound wound machine, the greater will the output of the dynamo become, while a decrease of flow through the series coil will lower the output.

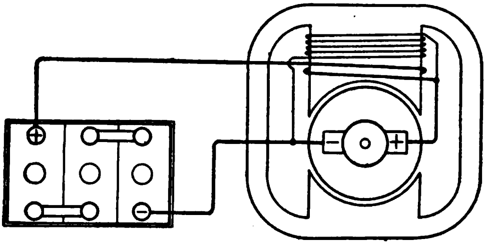


Figure 14.—Compound Field Winding.

The reversed series connection is shown in Figure 15 and it will be seen that the whole difference between this form and the compound wound machine lies in the difference in direction of the flow through the series field. In this case the shunt winding is acting at all times to make the upper pole positive and of a strength corresponding to the ampere-turns in the shunt coil. All of the current that leaves the dynamo must pass around the series winding and inasmuch as this current flows through the series coil in a direction opposite to that of the shunt field current, its effect will be to oppose the shunt field and weaken the total strength of the magnet.

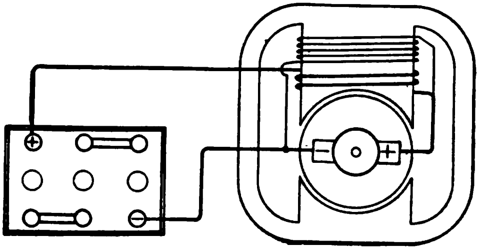


Figure 15.—Reversed Series Field Winding.

The normal tendency of the dynamo would be to increase the voltage and output in amperes with increase in speed, but this same increase of output passing through the reversed series winding tends to overcome part of the strength of the shunt field, weaken the magnet, and reduce the output. With this form of winding it is impossible for the dynamo output to exceed a certain value because of the opposition introduced by the series winding and dynamo regulation is thereby obtained.

One brush or one set of brushes will always be positive and the terminal connected to the positive brush side is then called the positive terminal. The remaining brush or set of brushes with the corresponding terminal or connections will then be negative. Should the flow of current around the fields be reversed in direction, the polarity of the brushes will also be reversed. With some designs of dynamo it is not desirable that such a thing should take place, while with others it is immaterial.

The initial flow around the fields is determined by the direction of the flow from the armature into the brushes and the direction of this flow from the armature is determined by the direction of magnetic flow between the field magnet poles, that is to say, the flow is determined by which pole is positive and which negative. It is assumed in this case that the direction of armature rotation remains the same at all times.

Because of the fact that the field magnets are magnetized by the flow of current around them it is often asked how the dynamo starts to generate, inasmuch as there can be no flow to start with and therefore no magnetism produced. This difficulty is taken care of by a natural characteristic of iron, this being the practical impossibility of completely demagnetizing the metal. A certain amount of magnetism, called "residual magnetism," will remain in the softest iron field cores even with the dynamo idle. When the armature starts to rotate this residual magnetism, which is the same in polarity as that obtaining when the dynamo last operated, causes a slight flow of lines of force through the armature. This allows a low voltage and small current to be generated in the armature, and this small current flowing through the field coils strengthens them to such an extent that the current flow is further increased. The dynamo "builds up" very rapidly in this way until the full voltage and output is reached.

If the flow of current around the fields should be reversed from its usual direction, the residual magnetism remaining would be of opposite polarity from the normal, and when the dynamo was again used its terminal polarity would be changed. That is, the terminal that was positive would be negative and the terminal that was negative would be positive. Should this condition remain, the dynamo would send its current through the battery in the wrong direction with the result that the battery would suffer an extremely rapid discharge and would soon be damaged permanently.

In order to restore the field magnets to the proper polarity it is necessary that a flow of current be sent through the windings in the proper direction. Should a test at the dynamo show that the current flow remains in the wrong direction, it may be corrected as follows: First make sure that the connections between dynamo and battery are correctly placed. This means that the positive side of the battery should be connected to the dynamo terminal that should be positive, while the negative side of the battery should be connected to the dynamo terminal that should be negative. With these connections made, with a fully charged battery, and with the dynamo idle, the cut-out should be closed several times and allowed to remain closed for two or three seconds each time. Should the cut-out tend to remain closed (if of the electromagnetic type), starting the engine will allow it to open. The flow of current through the dynamo under these conditions will restore the proper polarity at its terminals. Many types of dynamos now in use change their polarity to that of the battery the first time that the cut-out closes, and in this case it would not matter which way the connections were placed as far as the dynamo and battery were concerned.

The above remarks regarding dynamo polarity do not apply to machines having permanent magnet fields. With permanent magnets placed on the dynamo in a certain position, the brushes and terminals will be of a polarity that corresponds to the position of the positive and negative magnet poles with reference to the armature. Removing the magnets and replacing them in a position exactly opposite to the one originally occupied while the direction of rotation remains the same will reverse the polarity of the dynamo brushes and terminals. This polarity can only be restored to normal by replacing the magnets in their proper position. No amount of flow from the battery through the dynamo will have any effect on the fields for the simple reason that this flow of current does not pass around or affect the fields in the same way as with the electromagnetic type previously discussed. A flow of battery current through the dynamo in a wrong direction, however, will serve to weaken the permanent magnets of this type of machine and every precaution should therefore be used to avoid wrong connections in the wiring.

The polarity of any wire or any terminal may always be determined by attaching extra lengths of wire to each of the terminals or each side of the circuit to be tested. If the loose ends of these wires be then immersed in water to which has been added a small quantity of acid or salt, the wire attached to the negative side will give the greater amount of bubbles, Figure 16. The wire attached to the positive side will show very few, if any, bubbles. In making this test the wire ends should be separated by one-fourth to one-half inch. This test may be applied to dynamos while they are in operation, to batteries, or to any other wires when both sides of the circuit may be reached.

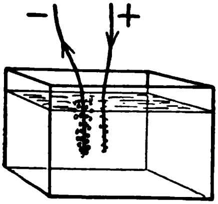


Figure 16.—Water Test for Polarity of Wire Ends.

ARMATURE

With very few exceptions, all lighting dynamos are made with a form of armature known as the "drum armature." The coil and commutator connections for this type are shown in Figure 17. This illustrates the principle used in handling the work by showing the connections for four coils and four commutator

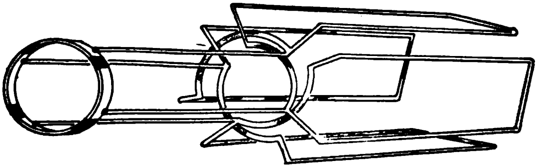


Figure 17.—Arrangement of Coils on a Drum Armature.

bars. In actual practice this number is increased according to the size of the machine. It will be seen that the ends of one coil attach to adjacent commutator bars in such a way that all of the coils and all of the bars are electrically connected with each other. The bars are insulated from each other and the coils are insulated in each case, the interconnection being secured between coil and bar in each case, and not from coil to coil or from bar to bar. The design of such armatures is not important to the present discussion, but the connections should be understood because they make clear the results that are secured in certain tests.

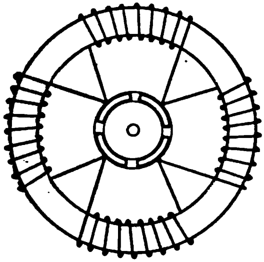


Figure 18.—Arrangement of Coils on a Ring Armature.

Another form of armature sometimes found in this work is that known as the "Gramme" type, or the "ring armature." The construction and connections for such an armature are shown in Figure 18. The armature core is in this case a hollow ring in place of a solid cylinder, but the connections between the coils and commutator bars and the complete circuit around the whole armature remain practically the same in effect.

COMMUTATOR

This part of the dynamo, in connection with the brushes, changes the alternating current generated in the armature windings to a direct current suitable for battery charging. The commutator consists of a series of copper bars arranged in a ring around the armature shaft and separated from each other by strips of mica or other insulating material. The commutator segments are connected to the armature windings as shown in Figures 17 and 18 and the brushes are carried in holders in such a position that they bear on the surface of the commutator in the best positions for the collection of the current at proper voltage and amperage.

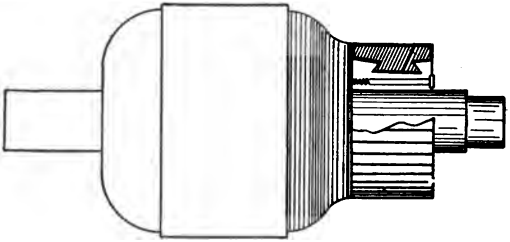


Figure 19.—Commutator Construction.

A longitudinal section through the commutator end of a dynamo armature is shown in Figure 19, this illustration indicating the proportions generally used for the commutator bars. It is necessary that the copper used be of a high degree of conductivity so that it will carry the current without undue heating and it is also necessary that the bars be of a depth sufficient to allow of a certain amount of wear from the brushes before the surface of the commutator comes down too close to the insulation on which the bars are supported from the shaft.

It is very essential that the insulation between adjacent segments be perfect, otherwise the coil to which these segments attach will be short circuited and the operation of the dynamo will be affected.

In order that the brushes may make a good contact with the surface of the commutator, this surface must be maintained in proper condition. That means that the commutator surface must be smooth and perfectly cylindrical in the form generally employed. Should the surface become dirty, scratched, rough or pitted it must be restored to good condition at once if the dynamo is to be maintained in good condition.

The commutator surface should be of a rather dark brown color and should have a slightly glazed appearance when in the best condition. Should an examination show it to be blackened or dirty it may be cleaned by holding a soft cloth slightly moistened with gasoline against the commutator surface while the dynamo is being driven by the engine at the slowest possible speed. Oil should never be used on the surface of a commutator, but lubrication may be provided by placing a small quantity of vaseline on a piece of soft cloth or leather and holding it against the commutator surface with the dynamo revolving. Even this lubrication should not be used unless the commutator surface shows signs of scratching after being cleaned. In many makes of dynamos the brushes are made from a composition that provides sufficient lubrication for the commutator surface.

If the surface of the commutator is rough or slightly scratched and pitted it may be dressed smooth with sandpaper. Emery cloth or emery paper should never be used because emery is an electrical conductor and will short circuit the commutator bars. Before using the sandpaper the commutator should be cleaned as described, the brushes should then be removed from their holders or the holders and brushes should be so supported that they do not touch the commutator surface. The engine should be run at the lowest possible speed so that the commutator is revolved. A strip of "000" sandpaper should then be cut just as wide as the commutator surface, no narrower under any circumstances, and this strip of paper should be placed over the end of a thin stick of equal width. By holding this paper against the surface of the revolving commutator slight scratches or pitting may be removed. Care should be used to bear evenly on the whole width of the commutator so that grooves may be avoided.

After the surface is even and bright, the engine should be stopped and every trace of copper dust and sand should be removed from the interior of the dynamo, either by wiping out with a cloth moistened with kerosene or by blowing out with air under pressure. The surface of the commutator will be improved and made very smooth if a soft pine stick is held against the surface while the engine is running. The job should be completed by dressing the ends of the brushes as described in a following paragraph.

Should the commutator surface show deep grooves or severe pitting it will be necessary to remove the armature from the dynamo, place it in a lathe and take the thinnest possible cut from the surface of the commutator. The comparatively slight thickness of the commutator bars should be borne in mind and no more metal should be removed than is absolutely necessary to obtain a smooth surface.

After turning a commutator in the lathe it will be necessary to "undercut" the insulation between the segments. It will also be necessary to perform this operation should the insulation be found even with or slightly above the surface of the copper bars at each side. To undercut the insulation means to remove sufficient material from the exposed edge so that its surface is about 1/32 inch below the surface of the copper bars.

The removal of the insulating material may be effected by using a very thin hack saw blade and exercising great care to avoid bridging from segment to segment with fine particles of copper. Figure 20 shows a partial section through a series of commutator bars, the white spaces representing the copper segments and the black portions the insulating material. At *A* and *B* are shown pieces of insulation that require undercutting. At *C* and *D* are shown sections when the work has been properly done and at *E* and *F* when improperly done. When the insulation is removed it must be taken out so that the surface is flat and the corners made with the copper segments are square. A knife file should be used following the hacksaw blade so that the corners may be cleaned out. If the surface of the insulation is left grooved the work will be practically valueless.

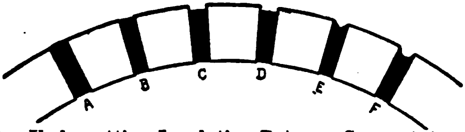


Figure 20.—Undercutting Insulation Between Commutator Segments.

Sparking at the brushes is usually caused by a commutator surface in poor condition, by improperly fitted brush ends, or by high insulation between the segments. Sparking may also be caused by brushes that do not rest on the commutator in the proper position, although this condition should not be met with unless the dynamo has been taken apart and wrongly reassembled. Other causes of sparking may be in the brushes themselves or trouble in the armature windings, which will be taken up in a later chapter.

While an examination of the commutator is being made it will be advisable to look carefully for segments that are loose, or too high or too low, that is, higher or lower than those adjoining. Loose segments will necessitate the return of the dynamo or armature to its makers, although high or low segments, provided this condition is not caused by looseness, may be corrected by turning the commutator in a lathe.

It will be noted that the wires coming from the armature windings are fastened to the commutator bars by soldering. These wire ends should be examined to make sure that they are tight, because the excessive heat that is sometimes generated in the dynamo may melt the solder and cause it to be thrown out of place. The remedy is to replace the wire ends and resolder them with hard solder and neutral flux.

BRUSHES

The brushes that collect current from the commutator are generally made from very fine grained carbon and this carbon is often combined with other substances such as graphite for purposes of lubrication and smooth running. Metal brushes made from tightly wound coils of copper wire gauze are sometimes used, although they are comparatively rare. Brushes are sometimes made by placing carbon around a copper core, the use of any one type depending on the design of the dynamo and the ideas of the makers. Because of the fact that it is not always possible to know just what calculations and allowances have been made in the design of the machine, it is a safe rule to follow always to replace brushes with others secured from the makers of the machine being handled. While other brushes might be satisfactory, there is always a doubt.

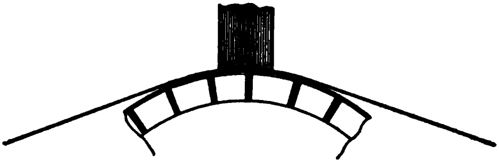


Figure 21.—Fitting Brush-End with Sandpaper or Cloth.

The electrical resistance between brush and commutator depends chiefly on how well the brush end fits the commutator surface against which it bears. High resistance lowers the efficiency of the dynamo and is the primary cause of more serious troubles. For these reasons the brush ends should always be properly fitted. This operation is performed as follows:

A strip of "000" sandpaper should be cut so that it is at least as wide as, and preferably a little wider than, the end of the brush to be handled. With the dynamo idle, the brush should be drawn away from the surface of the commutator so that the strip of paper may be drawn between the brush end and the commutator with the sand side toward the brush, Figure 21. The paper should then be drawn back and forth under the brush end and should be held so that it follows the surface and curve of the commutator while passing under the brush. The sand will remove enough of the brush end to allow a perfect fit on the commutator surface to be secured. After all roughness and unevenness have been removed from the brush, the end should be carefully wiped with a clean soft cloth. All particles of dust should be removed from the interior of the dynamo with a cloth moistened with kerosene or by blowing them out with air. Each brush should be dressed in this way, even though only one seemed to need the treatment. Great care should be used in dressing the ends of regulating brushes (the use of which will be explained in Chapter V), and they should always be dressed after moving them to a new position. It is absolutely essential that the brush ends shall make perfect and full contact over their entire section.

The brushes are practically the only part of the dynamo that will require periodical replacement. It is not possible to state any definite time that brushes should last; this depends on the design and construction of the dynamo. They should be examined occasionally and their length noted. When it is seen that they can wear only one-eighth of an inch more before allowing their holders or springs to touch the commutator, they should be removed and replaced with new ones. A brush should be expected to wear at least a year, although this time may be affected by many conditions. New brushes should always be fitted to the commutator surface by the method described above.

The brushes are carried in the proper position by holders of various forms. Some holders fasten tightly to the brush and move with the brush as it wears and as it follows the commutator surface, Figure 22. Other forms of holder provide that the brush slide freely in the holder, and in this case the holder itself remains stationary. In all cases the brushes are insulated from the holders or else the holders are insulated from the balance of the dynamo parts. Attached to the brush is a short length of flexible wire, usually called the brush "pigtail," and it is through this wire that the current is taken from the brush to the terminal connections, or in some cases, to a connection with the metal of the dynamo case for ground return systems.

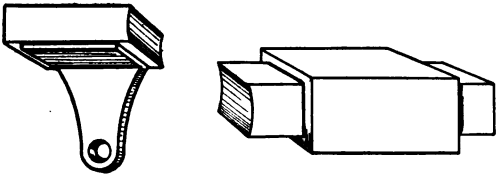


Figure 22.—Pivoted and Sliding Brush Holders.

The brush should be free to move at all times. If fastened securely to the holder, the holder should be free to move on the pivot that supports it, and if any binding is present, the dynamo output will be affected. If the brush slides in the holder, care must be used to see that the sides of the brush do not bind under any conditions. Should binding be found at this point, the sides of the brush may be carefully dressed with a fine file until a free sliding fit is secured.

The brushes are held against the commutator surface by means of springs of various forms and types. The tension of these springs is usually adjustable by some means, either by moving one end of the spring from notch to notch of an adjustment segment, by tightening or loosening a holding screw or by some other easily discovered means. The tension on brushes varies from an ounce or two up to nearly two pounds, depending on the design and requirements. In all cases the tension should be sufficient to maintain a good running contact, that is, so that the dynamo output will not be impaired and so that sparking will not take place with other factors taken care of. The tension should be as low as is possible and still secure good contact. More than this will cause excessive wear and overheating. See Figure 23.

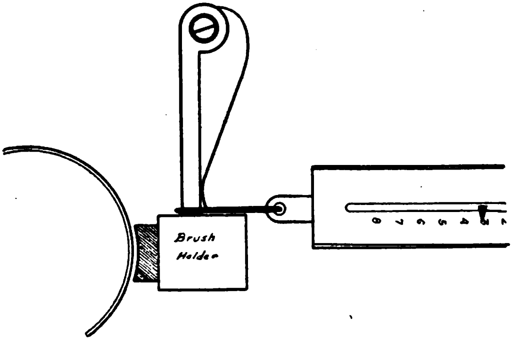


Figure 23.—Testing the Tension on Brushes by Means of Spring Balance.

STARTING MOTORS

The starting motor embodies the same principal parts as the dynamo, that is, it consists of an armature with its commutator, a set of brushes, field windings and field magnets. The most apparent difference between these units is in mechanical construction, the motor being heavier and being made from larger, stronger parts. Outside of the difference in action, the most noticeable electrical change is in the method of connecting the field windings. For motors that are separate units, that is to say, motors that are not combined with the dynamo, the series field winding is invariably used because its characteristics are more desirable for the work of starting.

It will be seen from an examination of Figure 13 that a series winding would send all of the current passing through the machine into the fields and then this total flow of current passes through the armature. The magnetic strength of the fields becomes greater with increase of current flow and by thus sending the whole flow through the fields they are made of the greatest possible strength. The same statement applies to the armature, the great volume of current making the armature pull as great as can be secured.

The maximum flow of current through a starting motor varies according to the difficulty of starting the engine from rest, being large in some cases and comparatively small in others. At a pressure of six volts the starting amperage may be anywhere between seventy-five and three or four hundred. With higher voltages the amperage is reduced for the reason that the power is measured in watts and the same number of watts may be secured by using a higher voltage with a smaller flow.

The power required in starting is usually between one-half horsepower and two horsepower, depending on the size of the engine and its design. This starting load puts a very severe strain on the battery, and if the flow is allowed to continue for more than a few seconds, great damage may result. The form of battery used for this work is well able to stand these heavy discharges and it is not the amperage of discharge that does harm so much as the withdrawal of such a great percentage of the available current from the battery. Fifteen minutes of rapid running will just about make up for the current drawn during thirty seconds' use of the starter with an engine that is rather hard to crank, and for this reason the starter should be carefully used and never demonstrated or used unnecessarily. The final result of improper use of the starter is a discharged battery, and it is this condition of discharge that harms the battery, not the heavy current drawn for starting.

In order to allow a motor of reasonable size to do the work it is connected to the engine through reduction gearing of some form. This gearing may take the form of chains or may be made up of spur, bevel or worm gears in combination with suitable shafting. The drive ratios ordinarily employed allow the starting motor to run from five to twenty-five times as fast as the engine crankshaft is revolved during the cranking operation. This ratio applies to starting motors that are separate units. Combined motor-dynamos usually have lower ratios, and in fact in some cases may operate at engine speed. A very common ratio for motor-dynamos is between two and one-half to one and three to one.

MOTOR-DYNAMOS

This word is used to designate the machines that are combined electrically, having one or more parts that perform functions during the generation of current as well as during the starting operation. The machine in which a separate motor and dynamo are enclosed by the same housing is not called a motor-dynamo in this book.

In all motor-dynamos it is necessary to provide two field windings, one a series winding for starting motor action and the other a shunt winding for the efficient generation of current, Figure 24. In some cases an additional winding is used for the purpose of regulating the output of the machine as a dynamo. In this last case the field magnets will carry a shunt winding for generating, a reversed series winding for output control and another series winding of heavier conductor for starting the engine as a motor. This system is used in Splitdorf motor-dynamos.

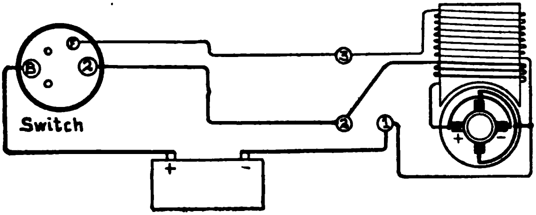


Figure 24.—Compound Wound Motor-Dynamo (Ryneto Type).

Other designs make use of a third field winding for purposes of regulation, but do not use the reversed series connection. One of these is found in the U. S. L. system which incorporates a compensating coil on one of the field magnet poles, this coil being energized through the current drawn off the commutator by a regulating brush. The action of this compensating coil is to assist the shunt windings at low speeds, but to oppose them at high speeds because of the change of direction in the current flow through the regulating brushes.

Motor-dynamos make up a very important class and also a very large proportion of the applications in use. They may be divided into several types, according to their construction and the principles involved in their operation. While the two types just mentioned partake somewhat of the characteristics of those to be mentioned hereafter, they should be considered separately because of the additional field winding that is used to produce the regulation of current.

One of the commonest classes of motor-dynamos is the one making use of a machine with one armature with one commutator for both starting and charging. The fields carry a shunt and a series winding. During the starting operation the current flow passes through these windings in such a direction that they assist each other and the machine becomes a compound wound starting motor. When the speed of the motor-dynamo is increased to a point at which its generated voltage will overcome the battery voltage, it becomes a dynamo with the shunt field current flowing in the same direction as during starting, but with the series field current flowing in the opposite direction. This makes it a dynamo with a reversed series field coil, and this reversed series winding serves to limit the amperage during charging. This action is shown in Figure 25. When the starting switch *S* is closed, the

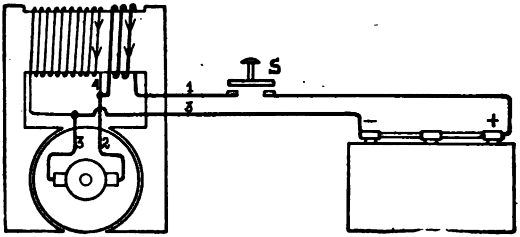


Figure 25.—Compound Wound Motor-Dynamo Providing Reversed Series Regulation.

battery current flows through the positive wire *1* and around the series field winding in the direction of the arrows, thence through the wire *2* to the right-hand brush, through the armature to the left-hand brush and to the battery through the negative wire *3*. The right-hand brush is positive and the left-hand one negative. Current then flows from the positive brush side through the wire *4* and around the shunt field coils in the direction of the arrows and back to the negative brush side. It will be seen from the arrows that the current flow is in the same direction around both field windings.

Now consider what happens when the dynamo voltage overcomes that of the battery. The flow of current will then be from dynamo to battery and at the instant of reversal there will be no flow through the series field, although the flow will continue through the shunt coils. This is true because the current stops coming from the battery and for a moment might be said to stand still in the lines connected to the battery. The dynamo voltage is now causing a flow through the shunt field in the original direction and because the fields are maintained with the same polarity the right-hand brush remains positive. With the flow from dynamo to battery, the direction of current through the shunt coils will be as shown by the arrows, but the flow through the series field will have been reversed and will be in the direction opposite to the arrows, which of course causes the upper coils to become a reversed series winding. A reverse current cut-out may or may not be used with this system. Some makers, such as Allis-Chalmers, use an electromagnetic cut-out, while others, like Dyneto and Entz, allow the dynamo and battery to remain connected as long as the starting switch is closed. This subject will be more fully covered in Chapter V.

Another class of motor-dynamos makes use of a series and a shunt field winding, but with the difference that the series field is not used as the principal method of current control, while the shunt field is neglected, or is of minor importance, during charging. These machines make use of an automatic cut-out in the charging circuit which opens the connection between battery and dynamo when the dynamo voltage is below that of the battery and while the starting switch is open. The connections for such a system are shown in Figure 26, which illustrates the principle involved, although in practice the wiring is not always placed exactly as shown for manufacturing reasons. With the starting switch *S* closed, current flows from the battery through the wire *1* and the series field to the left-hand brush, then through the armature to the right-hand brush and back to the battery through the wire *2*. When the engine has been started and the starting switch opens, the battery is disconnected from the motor-dynamo by the open starting switch and by

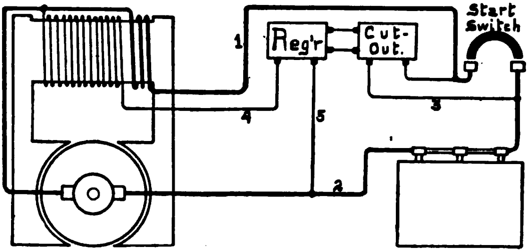


Figure 26.—Motor-Dynamo with Separate Regulator and Cut-Out.

the cut-out which is always open when the dynamo voltage is below that of the battery. When the dynamo is running at a speed sufficient for charging, the cut-out closes and the dynamo and battery are connected through the wires *1* and *3* on the positive side, and the wire *2* on the negative so that charging commences. It will be noticed that the shunt field wire leads to the regulator and the dynamo output is controlled by the action of this regulator in limiting the shunt field current. The current from the left-hand brush passes to the shunt field, then through the wire *4* to the regulator and back through the wire *5* to the right-hand brush. The current that flows through the series field to the cut-out during charging passes in a direction the reverse of that found during starting so that this series field acts to limit the dynamo amperage. This action is not depended on altogether, but the additional regulator in the shunt field circuit is supposed to perform this function. This is the principle used with Allis-Chalmers motor-dynamos, also with North-East, Remy, and Simms-Huff units.

Other motor-dynamos use an automatic cut-out, but control the dynamo output by other means than the one shown in Figure 25. For example, Wagner, Bijur, and Westinghouse motor-dynamos use the "third brush" method of control, while Jesco motor-dynamos make use of a "bucking coil" on the field magnets, both of which methods of control will be explained in Chapter V.

Still another class of motor-dynamos, represented by Delco equipment, makes use of a shunt and a series field winding and also provides separate windings and two separate commutators for the armature. The principle of connection used with such a machine is shown in Figure 27. With the engine idle the open cut-out switch disconnects the battery from the brushes on the dynamo commutator *D* and also from the lower shunt field. The dynamo or current generating part of the unit is therefore inoperative. When the starting switch *S* is closed, current flows from the battery through the wires *1* and *2* to the upper series field and then through the wire *3* to the brush resting on the motor commutator *M*. Passing through the motor windings on the armature, the current returns to the battery through the wire *4* and the engine is started.

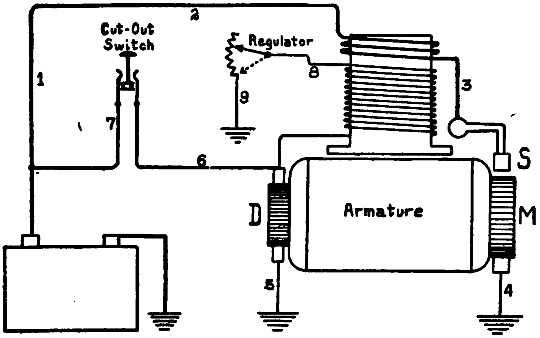


Figure 27.—Double Commutator Motor-Dynamo with Manual Cut-Out (Delco Type).

With the engine started, the switch *S* is allowed to open and the series field and motor windings on the armature are no longer energized. The motor-dynamo is then driven by the engine as a dynamo and with the cut-out switch closed, current flows from the dynamo commutator *D* through the brushes and wires *5*, *6* and *7* to the battery for charging. The shunt field is connected to the dynamo commutator brushes and the flow through the field windings is controlled by the regulator. The shunt field current passes from the upper brush through the field windings, then through wire *8* to the regulator and back through wire *9* to the lower dynamo brush.

COMBINED UNITS

While the separate dynamo and motor, together with the motor-dynamo, make up by far the greater part of all the equipments in use, other combinations are found in lesser numbers. One of these is the ignition-dynamo. This machine is made by attaching to a separate dynamo of any type the devices that are necessary for the production and distribution of the ignition current for the spark plugs.

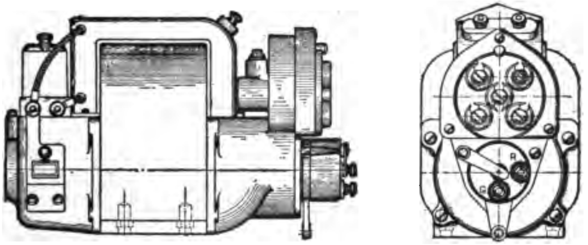


Figure 28.—Ignition-Dynamo (Remy).

One type of ignition-dynamo, Figure 28, makes use of a breaker, or interrupter, and a high tension distributor of the conventional magneto type mounted on one end of the dynamo, either the end that carries the dynamo commutator and brushes or the opposite end. The operation of these ignition parts differs in no way from the operation of similar ones used on magnetos, the attachment to the dynamo being made simply because it affords an economical method of mounting and does away with the necessity for providing a separate magneto with its drive and base. The combination of these ignition parts in no wise affects the starting and lighting features of the machine and in this connection the ignition units may be disregarded. It should be understood that this construction does not allow for what is known as a "self-contained high-tension" magneto being incorporated with the dynamo, but uses a separate transformer coil just as does the magneto of the type that requires a separately mounted coil. This type of machine has been produced by Gray & Davis, National, Remy, and Westinghouse.

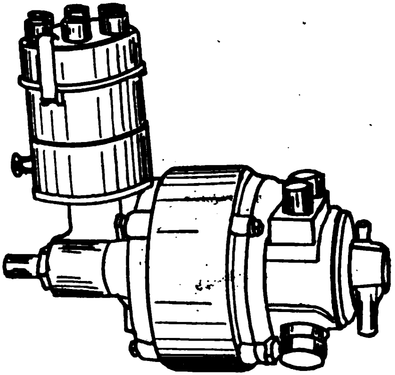


Figure 29.—Dynamo with Vertical Ignition Head (Westinghouse).

Another consolidation of electrical devices is met with when the ignition units are mounted on the dynamo case and are driven from the same shaft that drives the dynamo, Figure 29. In this case the ignition parts include a breaker or interrupter together with a high tension distributor carried in a small housing and with their drive shaft attaching through gearing in the dynamo drive shaft. The separate transformer coil may be mounted on the dynamo or may be carried at some other point on the car. This combination is also called an ignition dynamo or "dynamo with ignition."

It is also possible to mount the type of ignition units just described on a motor-dynamo just as they are mounted on a dynamo. This is the construction so often found with Delco installations, Figure 30, and has also been used by such makers as Remy. A single piece of machinery then performs functions of starting, lighting and ignition, and is often called a single-unit machine. The term "single unit" is commonly applied to the motor-dynamo also, although its use in this connection is somewhat confusing. The various combinations may be distinguished by calling a system made up of separate dynamo, separate motor and separate ignition unit, a "three-unit" system; a motor-dynamo or ignition-dynamo with separate ignition or motor, a "two-unit" system; and a motor-dynamo with ignition a "single-unit" system.

The combination of motor and dynamo in one case while making them separate electrical units is in fairly common use. The electrical design of the parts of the installation does not differ in any way from that used when they are placed entirely away from each other. When this construction is used, the dynamo unit is generally driven from the shaft or chain sprocket that comes direct from the engine crankshaft, so that a proper drive ratio for the dynamo may easily be secured. The motor is then mounted at one side, or above or below the dynamo,

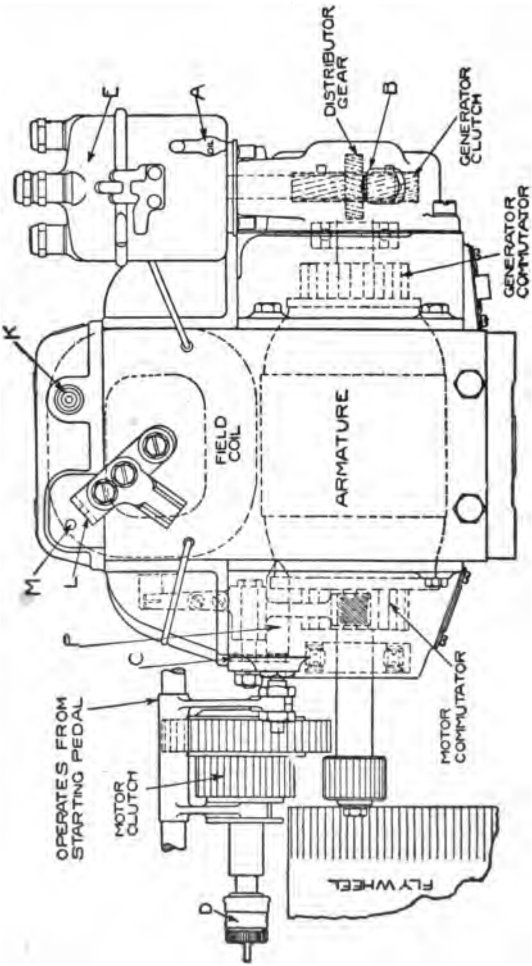


Figure 30.—Delco Motor-Dynamo with Ignition Head.

and drives to the main dynamo shaft through a reduction gearing that allows of the proper ratio for starting without interfering with the dynamo drive. See Figure 31. The dynamo is always driven while the engine is running because of its direct connection with the main drive shaft. The motor, however, is only in operation while the engine is being started and at all other times is allowed to remain idle and disconnected from the drive shaft. The location of the units and the construction used with them will always be apparent from an examination.

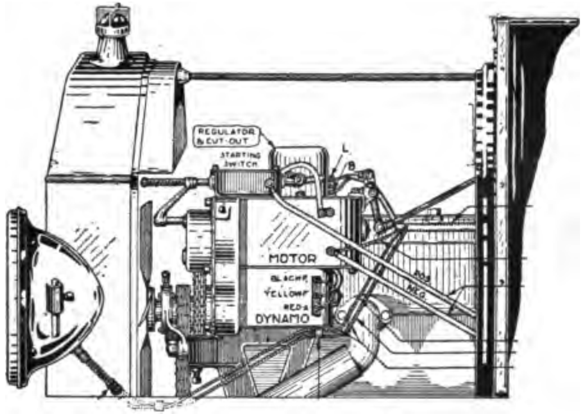


Figure 31.—Double Deck Motor and Dynamo (Gray & Davis).

Some modifications of the types described are in use, such as the tandem system, which places the motor and dynamo end to end. They are mechanical variations only and are not important from the electrical standpoint. Many such combinations are adopted because of the limited room or difficult drive connections that must be considered.

CHAPTER III

STORAGE BATTERIES

Each cell of a storage battery contains two kinds of plates, called positive and negative, made from compounds of lead and immersed in a liquid composed of sulphuric acid and water. A chemical action takes place between the plates and the liquid and the result of this chemical action is a flow of electricity through wires that are attached to the battery terminals. Therefore, the battery does not store, and does not contain, electricity, but is capable of generating a flow of electric current because of the action that takes place in the battery. In order to bring the elements of the battery into such condition that they will cause a flow of current, it is first necessary to send a flow of electricity through the battery. The energy of this current being sent through the battery is consumed in making one series of chemical changes, and when wires are connected to the battery, this same series of changes takes place in a reverse order and most of the energy absorbed from the flow of charging current is given back into the wires.

As already mentioned, the cells are made up of plates and liquid. The plates are in turn made up of a metal framework, called the "grid," Figure 32, and a paste, called the active material, with which the spaces in the grid are filled. Adjacent plates are prevented from touching each other by the use of wood separators, Figure 33, placed between them.

The jar in which the plates, separators and liquid are carried is made from some form of insulating material, often containing rubber, compounds of pitch and other materials that insulate while resisting the action of the acid in the liquid.

The grids are made from lead with which has been alloyed antimony to give the metal the necessary stiffness. Various designs and forms are in use, but they consist in a general way of vertical and horizontal bars usually spaced about three-fourths of an inch apart, measuring across the plate and about one-fourth inch apart measuring up and down. The grids, and consequently the plates, vary in thickness from about one-eighth inch up to three-eighths. The thickness of the plate has a great deal to do with the rate in amperes at which current may be drawn from the battery. Very thin plates allow the liquid in the cell to reach through them with comparative ease and a very heavy current may be taken from such a battery, while the thicker plates will only allow comparatively

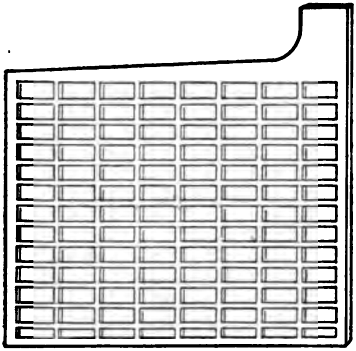
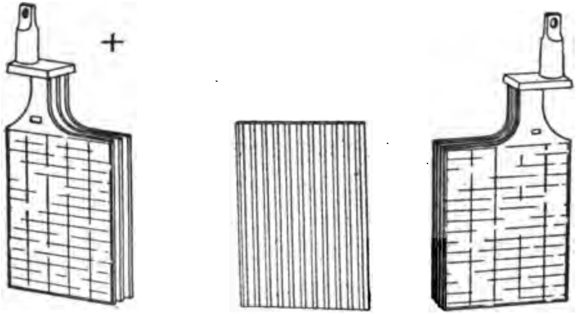


Figure 32.—Grid for Battery Plate.

low amperages to be drawn through the wires. The bars of the grid are formed and spaced in such a way that they tend to hold the active material firmly in place.

After the grids have been formed they are filled with the active material by the process called "pasting," and this form of plate is called a "pasted plate." The active material is made from lead oxides, sometimes combined with other materials to give hardness and toughness and to make the plates porous so that the liquid can act on the material. The mixture is made into a paste with weak solutions of sulphuric acid and water, and the spaces between the bars of the grid are filled with this paste. After the material has set or hardened, the pasted plates are assembled with their separators in a jar. The cell contains an uneven number of plates, Figure 34, there being one more negative than positive, and the plates are placed alternately and so that both outside plates are negative. The liquid, composed of acid and water, is then poured into the jar until it covers the plates to a



Figures 33 and 34.—Positive Plates, Separator and Negative Plates.

depth of one-quarter to three-eighths of an inch above their upper edges.

When the cell has been assembled all the positives are joined together and all of the negatives are similarly fastened together with connecting straps that join the lugs cast at one of the upper corners of each grid. The positive connecting strap is attached to the positive terminal of the cell or battery, while the negative strap is fastened to the negative terminal.

A flow of electric current is then sent through the cells, the positive side of the charging current being attached to the terminal that will be positive and the negative side of the source of current being connected with the negative terminal. As this current flows through the cells a change takes place in the material of the plates and the positives turn to peroxide of lead while the negatives turn to sponge lead. When the material in the grids has been completely transformed, which usually takes several reversals of current flow, the plates are said to be "formed" and the battery is charged.

The positive plates are now dark red or brownish red in color and are hard enough to resist scratching with the finger nail. The negatives are gray and are soft enough to be easily dented with any hard substance. The material must be porous in each case, and water poured on dry positive plates should show through on the opposite side almost immediately. It is very desirable that the material in the plates be as tough as possible, so that it will not readily fall to pieces, and it should also be as lightweight as possible so that the surface exposed will be large when compared to the total weight. High grade batteries of these types will deliver a power of between nine and twelve watt-hours for each pound of weight, this being the equivalent of from one and one-half to two amperes flow at six volts pressure. The battery will gradually deteriorate while in use, and when its age is between eighteen months and three years, the negative plates will have suffered a change in the form of the material so that it is an economy to replace the battery with a new one.

THE CELL

Inasmuch as all batteries must be made up of individual cells and as all the cells in one battery are exactly alike, the subject will be treated as the cell rather than the battery, and it will be understood that everything said about the cells applies to the battery as a whole.

The voltage obtained from one cell does not depend on the size or weight of the cell, as it is the same whether the battery will give a flow of only a few amperes or of several hundred amperes. The normal voltage under operating conditions is two for the cell, this voltage varying, however, with the state of charge of the battery. When the material in the plates has been completely changed to peroxide of lead and lead sponge and the cell is fully charged, the cell voltage may be as high as 2.5, while with the battery discharged to a point at which no more current should be drawn, this voltage will fall to between 1.7 and 1.8 for the cell. The voltage while being charged will be higher than while being discharged, the charge voltage being between 2.1 and 2.6, while on discharge the voltage will usually run between 1.9 and 2.1. It will thus be seen that the voltage of the cell may give some indication of the condition of charge or discharge, a voltage below 2 indicating that the cell is discharged, while a voltage of 2 or more indicates a satisfactory condition of charge. It should be understood, however, that the voltage does not form an entirely dependable indication because it is easily possible to have a high voltage with a cell that is capable of giving very little flow of current for useful work, while the voltage of a cell that is in good condition to do a great deal of work may be rather low. In making ordinary calculations it is customary to consider each cell as causing a pressure of two volts. Therefore, a three-cell battery is called a six-volt battery, a six-cell battery is a twelve-volt battery, etc. It should be borne in mind that a six-volt battery may give a pressure of seven and one-half volts, a twelve-volt battery may give fifteen volts, and so on for any voltage or number of cells.

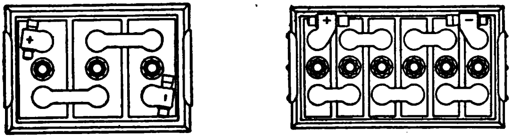


Figure 35.—Six- and Twelve-Volt Batteries with Cells in Series.

In order that the voltage of the whole battery may be equal to the number of cells multiplied by two, the individual cells are connected in series with each other. The series method, Figure 35, connects the positive of one cell to the negative of the next and the positive of the second to the negative of the third, and this connection is carried throughout the battery if it is desired to secure a voltage equal to the combined voltages of all the cells. It is possible to make other connections that will give a lower total voltage by placing a sufficient number of cells in series to give the desired pressure and calling these cells one section of the battery. Two of these sections placed with the positive terminals of the sections together and the negatives together, Figure 36, will give a voltage only equal to that of one section, and the two parts are then connected in multiple or parallel. This method of connection is used in some electrical systems that furnish a high voltage for starting purposes and a lower voltage for lighting and battery charging.

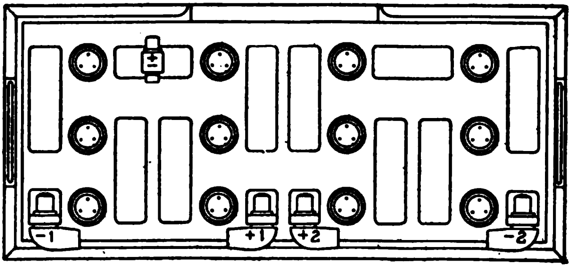


Figure 36.—Twelve-Cell Battery of Two Sections for Multiple Connection. —1 and +1, Terminals for Left-Hand Section. +2 and —2, Terminals for Right-Hand Section. Terminal Marked + and — on Left-Hand Section Is for a Neutral Wire to Provide Six-Volt Pressure.

Batteries are in use having three, six, eight, nine, twelve or fifteen cells and giving respectively six, twelve, sixteen, eighteen, twenty-four or thirty volts. All of these except the three-cell type may be divided into two sections or more. (See Figure 37.) Six-cell batteries are made to give either twelve volts or else six and twelve according to their connection. Eight-cell batteries always are arranged to give eight or sixteen volts. Nine-cell batteries may give eighteen volts or may be arranged to give six, twelve and eighteen volts. Twelve-cell batteries may be arranged for twelve and twenty-four volts or for six and twenty-four volts. Fifteen-cell batteries are arranged to give six or thirty volts. The higher voltage is always used for starting the engine, while the low voltages are for lighting or for lighting and charging.

The current that a cell will give is measured in ampere-hours or in watt-hours, generally by the former. An ampere-hour is the total quantity of current that passes in one hour if the flow is continuous at a rate of one ampere. An ampere-hour will also pass if a flow of one-half ampere is maintained for two hours and likewise one ampere-hour will pass if a flow of two amperes is continued for one-half hour or of four amperes for a quarter of an hour. The number of ampere-hours is found by multiplying the number of amperes flowing by the time in hours that the flow continues. Batteries are generally rated according to their ampere-hour capacity, this capacity being based on discharging the battery in eight hours. A battery rated as a 120 ampere-hour battery would give a flow of one ampere for 120 hours, or, theoretically, a flow of 120 amperes for one hour. This latter flow could not be secured in practice, however, because of the

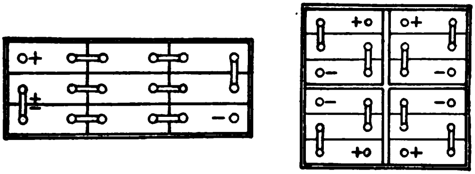


Figure 37.—Nine-Cell Battery (Left) with Neutral Terminal, and Twelve-Cell Battery (Right) Divided Into Four Sections.

action that would take place in the cells under such a heavy discharge rate. The 120 ampere-hour battery should give a flow of fifteen amperes for eight hours, thus giving its normal output of 120 ampere hours. At low rates of discharge, that is, with a less number of amperes flowing, it will be possible to secure more than 120 ampere-hours, while a high rate will decrease the available number of ampere-hours.

Batteries vary in capacity according to the size and weight of the plates that are in the cells and according to the number of plates used. The greater the positive plate surface exposed to the liquid in the cells, the greater will be the ampere-hour capacity of the cells. Batteries of three cells for automobile use range in capacity between sixty ampere-hours and one hundred and eighty ampere-hours, depending on the lamp and other equipment that must be handled. Batteries of more than three cells are of less amperage in proportion to the increased voltage, although the watts that may be secured will remain the same regardless of the combination of voltage and amperage used.

The watt-hour capacity may be found from the ampere-hour capacity by multiplying this latter figure by the voltage. One watt-hour is the power secured from a flow of one ampere under a pressure of one volt (equalling one watt) for one hour. A six-volt battery of eighty ampere-hours' capacity would therefore have a capacity of 480 watt-hours.

BATTERY CHARGE AND DISCHARGE

As previously stated, a charged cell has had its positive plates changed to peroxide of lead and its negatives to sponge lead. The liquid in the cells, which is made from a mixture of sulphuric acid and water, is called the electrolyte. The peroxide plate, the sponge plate and the electrolyte make up the working parts of the cell.

When the battery is connected to the wiring circuits of the car so that it starts the engine or lights the lamps, an action immediately begins to take place in the cells and between the plates and the electrolyte. A part of the sulphuric acid in the liquid begins to combine with the lead in the plates to form lead sulphate, and the surfaces of both plates are gradually covered with this sulphate. The percentage of water in the electrolyte is increased because of the combining of part of the oxygen and the sulphur of the acid with the lead of the plates, leaving the hydrogen and oxygen in the form of water, which is a combination of these two gases. The surfaces of the plates thus change slowly to lead sulphate, while the liquid becomes more nearly pure water. When this action has penetrated a slight distance below the surfaces of the plates, the coating of sulphate causes the change to take place at a slower rate, and the battery will then give a smaller flow in amperes and at a lower voltage. When the discharge has continued until the normal output of the battery has been secured, damage will be done by further discharge, and it will then be necessary to send a charging current through the cells in a direction the reverse of the flow that takes place during discharge. The water analogy can be used here, comparing the battery to a tank that has been emptied and into which a flow of water must be sent in a direction the reverse of that taken by the water that was discharged from the tank.

With the charging current flowing, the sulphate of the plates combines with part of the hydrogen and oxygen in the liquid to form sulphuric acid. The positive plate then becomes peroxide of lead and the negative is left as sponge lead. This transformation continues until the sulphate is completely reduced, and the battery is then said to be charged. Further flow of current will not increase the charge nor the flow that may be drawn from the battery on discharge. It should be understood that the sulphate referred to here is not the injurious form that attacks the plates when they are said to be "sulphated," as a disease or trouble. Plates that are "sulphated," in the latter sense, are over-sulphated, and the deposit is then an almost pure and practically insoluble lead sulphate that prevents proper action in the cells.

The rate of flow through the battery while being charged depends on the ampere-hour capacity of the battery, and should never exceed a number of amperes equal to one-eighth of this capacity. That is, an eighty ampere-hour battery should not be charged at a rate in excess of ten amperes, or one-eighth of the total capacity.

The efficiency of a battery is greater with low rates of charge and discharge than with high rates. By efficiency is meant the proportion of current that may be withdrawn from a battery in comparison with the amount sent in on charge. The conditions of use on an automobile are favorable from an efficiency standpoint in some ways, although the conditions are hard on the battery in others. The action on the car is to give some charge while the dynamo runs and then some discharge as the lamps burn. Oftentimes the battery will be required to absorb the excess of dynamo output above the current being taken for the lamps, and at other times the battery will be called upon to make up a slight deficiency between the lamp load and dynamo output. This use of the battery is called "floating" it in the lines, and it is known that the efficiencies of floating batteries are higher than for those that are completely charged and then completely discharged.

The rate of discharge should not exceed in amperes one-eighth of the ampere-hour capacity of the battery, although rapid discharge is not very harmful to a battery provided it is not then allowed to stand in a discharged condition. The efficiency of the battery, if called one hundred per cent at a discharge rate of one-eighth of its capacity, drops with increase of discharge amperage until at one-sixth of the ampere-hour capacity the efficiency is about nine-tenths. At double the eight-hour rate, or one-fourth of the total capacity, the efficiency is about four-fifths, while a discharge that would empty the battery in one hour will allow less than half of the normal number of ampere-hours to be secured.

The greatest care that is necessary in allowing a battery to discharge is to see that it does not do so to such a point that the voltage becomes abnormally low. Under no conditions should discharge be continued when the voltage is 1.7 per cell, and if the current flow from the battery is carried past this point serious damage will result from over-sulphation on the plates, distortion and warping of the plates, and the formation of harmful corrosion on the metal of the grids.

The proper charging rate for the different batteries may be found from the information given on the nameplate attached to the battery case. In most cases two different rates will be given, one marked "start," and the other "finish," or "24-hour." The starting rate is the greatest that the battery will stand, and should be as great as the highest rate of charge that the dynamo can send through the battery. The finish rate is used when the battery is charged from an outside source of current other than the car's dynamo. The high rate is between one-sixth and one-tenth of the capacity in ampere-hours, generally about one-eighth. The finish rate is approximately one-fourth to one-half of the high rate, generally about one-third.

When it is necessary to charge a battery from an outside source, it must be remembered that the positive side of the charging current must be attached to the positive terminal of the battery and the negative of the charging current to the negative of the battery. The polarity of any wires may be determined by immersing their ends in water to which has been added a small amount of acid or salt. The wire that comes from the negative side of the source will bubble most.

The charging current must always be direct current. Alternating current connected directly to the battery without the use of a rectifier will not only fail to charge the battery, but will do positive damage. Direct current is abbreviated, D. C., and alternating current, A. C. It will be necessary to ascertain which kind of current is supplied by the charging circuit to be used, and if it is alternating, a rectifier must be inserted between source of current and the battery to be charged.

With a supply of direct current at hand, the battery may be charged by inserting such a resistance in the line as will allow the proper amperage to flow through the cells. The high voltages found on lighting and power circuits in buildings would send a damaging flow through the cells, and it will always be necessary to use incandescent lamps or other forms of resistance with such current and voltage. (See Figure 38.)

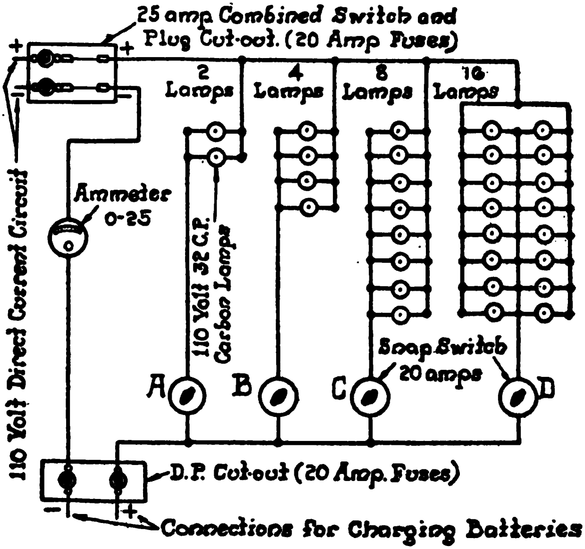

25 amp Combined Switch and Plug Cut-out. (20 Amp Fuses)
+
+
−
2 Lamps
4 Lamps
8 Lamps
16 Lamps
Ammeter 0-25
110 Volt Direct Current Circuit
110 Volt 32 C.P. Carbon Lamps
Snap Switch 20 amps
A
B
C
D
D.P. Cut-out (20 Amp. Fuses)
−
+
Connections for Charging Batteries

Figure 38.—Battery Charging with Lamps for Resistance.

A sufficient number of incandescent lamps may be lighted at one time to allow the amperage to flow at the rate marked "finish," or "24-hour." If the lamps to be used are marked on their bulbs with the number of watts required, as is usually the case, enough lamps must be lighted to give a total number of watts when added together that will allow the proper amperage to flow. The amperage desired should be multiplied by the voltage of the charging line, this giving the number of watts required. Enough lamps must then be used to make up this number of watts. Thus, if the battery requires three amperes charge and the charging current is 110 volts, three times this voltage gives 330 watts as the result. Seven 50-watt bulbs will make 350 watts, which will be just about right. If the lamp bulbs are marked in candlepower, their wattage may be found by multiplying the candlepower by three for carbon filament bulbs, or considering a 16 c.p. bulb as a 50-watt bulb and a 32 c.p. bulb as a 100-watt bulb, etc. If tungsten lamps must be used, the candlepower and wattage are equal, that is, a fifty-candlepower bulb is a fifty-watt bulb.

A battery should have each cell filled with pure water until the level is above the tops of the plates before any charging is done; this applies whether the battery is charged on the car or from an outside source. When giving an outside charge it is desirable that the current should flow without interruption until the charge is complete.

ELECTROLYTE AND TESTING

From the explanation given of the action that takes place during charge and discharge, it will be seen that the proportion of acid in the electrolyte will give an indication of the condition of the battery, that is, whether it is properly charged or nearly discharged. The acid is much heavier than water, and as the proportion of acid in the liquid becomes greater, the weight of the electrolyte becomes greater. Therefore, the heavier the electrolyte, the more nearly charged the battery is known to be.

To find the condition of the battery by testing the liquid, a hydrometer is used. The hydrometer (Figure 39) is a glass tube having a hollow bulb and a weight at one end and a thin tube with a numbered scale at the other end. When this instrument is allowed to float in the liquid from the battery cells, the point on the scale to which it sinks indicates the weight of the liquid, because, of course, the hydrometer will not sink so deep into the heavy liquid with a large proportion of acid as it will into the liquid when almost all water. The scale is graduated accord-

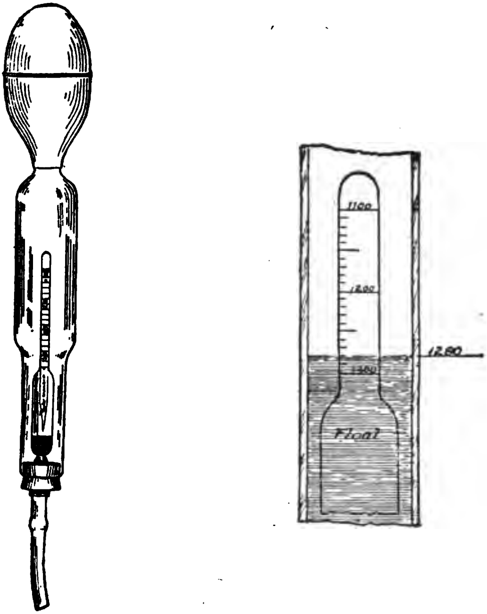


Figure 39.—Hydrometer Syringe and Hydrometer.

ing to the weight of liquids, known as specific gravity, which is their weight compared to that of pure water. On the stem of the hydrometer appear numbers from 1.100, near the top, to 1.300, near the bottom. With the battery fully charged the hydrometer will sink only to the point marked 1.300, or somewhere near that point; but with a discharged battery whose electrolyte is mostly water the hydrometer will sink to the 1.100 mark. Different degrees of charge are indicated by the hydrometer's sinking to points on the scale intermediate between the 1.100 and the 1.300 marks. The point indicated at the surface of the liquid is the specific gravity of the electrolyte. If the scale were long enough and the instrument placed in pure water, it would sink to the point marked 1.000, which is the basis of the scale. If the instrument were then placed in the kind of pure sulphuric acid used in batteries it would sink to about 1.835, which is the specific gravity of the acid generally used.

The hydrometer itself is usually carried in a larger tube with a small nozzle at its lower end that may be inserted into the cells, and with a bulb at the upper end so that some of the electrolyte may be drawn from each of the cells for purposes of test. In the top of each cell of every battery will be seen a small plug. This plug may be unscrewed or released from its lock and will leave an opening exposed that passes into the interior of the cell and through which the electrolyte may be seen, or the tops of the plates if the liquid is low enough. With the plugs removed, the hydrometer syringe, as the tube and bulb is called, may be inserted into the cell, and when the bulb is squeezed and allowed to expand some of the liquid will be drawn up into the tube and the hydrometer will float in this liquid. (See Figure 40.) After all pressure has been released from the bulb the specific gravity of that liquid may be noted on the hydrometer scale at the point where the instrument rises above the surface of the electrolyte. The gravity should then be noted and the liquid carefully returned to the same cell from which it was drawn. The same method should be used to find the specific gravity of each cell.

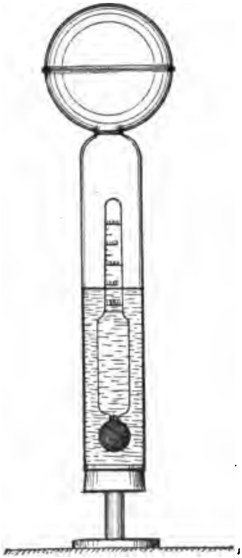


Figure 40.—Hydrometer Floating in Liquid Drawn Up Into Syringe.

If this gravity is between 1.250 and 1.310, the cell is well charged. If the gravity is between 1.200 and 1.250, the cell is at least half, but not fully, charged. Gravity between 1.150 and 1.200 indicates that the cell is nearly discharged, while gravity of 1.150 or below means that the cell is discharged to a point at which no further discharge should be allowed. The gravity is often mentioned in "points," the difference between 1.200 and 1.250 being 50 points.

The specific gravity should not be tested until after the battery has been charged, should the water be found so low that it is necessary to add more to bring the liquid above the plates. If the battery is in good condition, the gravity will be within twenty-five points of the same in all cells. If there is a greater difference than this it usually indicates trouble in the cell or cells that are low. When, near the end of a charge, the specific gravity of the liquid in a cell does not show any increase for two hours or for three readings taken one hour apart, the cell is fully charged. At this time bubbles of gas should be rising through the electrolyte and showing freely on the surface.

BATTERY CARE

It is very essential that the storage battery have certain attention at regular intervals. The most important item in the care of a battery is that of adding pure water to each cell at least once each week during warm weather and at least every second week in cold weather while the car is in use. The water is added through the holes left with the vent plugs removed and may be easily handled by using the hydrometer syringe. A sufficient quantity of water should be placed in each cell to bring the surface of the liquid from one-quarter to one-half inch above the tops of the plates, this point being indicated in most cases by a rim that can easily be seen at the bottom of the hole with the plug removed.

The water used for this purpose must be distilled or else perfectly clean rain water. Tap water or water that has been kept in metal containers must never be used. Some city waters may be used, but it will always be necessary to make an analysis before their safety can be determined. Except when some of the electrolyte has been spilled from one of the cells, nothing but pure water should ever be added. In no case should undiluted sulphuric acid be used. If it is known that a part of the electrolyte has been lost through other means than by evaporation and the slight spray from gassing, the level may be brought up in the low cell by testing the gravity in the adjoining cells and then making enough electrolyte of this gravity to bring the level in the low cell to the required point.

Electrolyte is made by slowly pouring chemically pure sulphuric acid into distilled water until a mixture of the desired gravity is reached. Two and one-half parts of water to one of acid will make a mixture of about 1.300 specific gravity. Lower gravity is secured by adding more water. The mixture must be allowed to cool before it is added to the cell. If the water is poured into the acid, a violent action and throwing of liquid will take place.

The specific gravity of each cell of the battery should be taken at regular intervals, and if the whole battery is getting lower the fault should be looked for without delay. If one cell becomes lower, but the others remain normal, trouble in that cell is indicated. Care should be used when testing not to spill electrolyte on top of the battery, as it will cause corrosion at the terminals and partial short-circuiting of the cells. If it is found that one cell always takes more water than others, it is probable that the jar for that cell has become broken. The level of the liquid in the cells should not be above a point one-quarter to half an inch above the tops of the plates, because during charge the gassing that occurs will cause the electrolyte to overflow and cause damage outside of the cells.

At the time of testing or adding water to the battery, the terminals should be carefully examined for looseness or breakage, either at the connecting bars between the cells or at screwed or tapered connectors. No copper wires should ever be attached at the lead battery posts, as they will soon be eaten away by the action of the acid. Should the connections be found covered with corrosion or verdigris, they should be washed with ammonia water, and in any case should be covered with a coat of vaseline to prevent such action by the acid.

The battery must be firmly secured in its box so that movement from the motion of the car is impossible. Wood cleats should be placed under the battery and fastened into the bottom of the box. The space all around the battery and on top should be free and open for the circulation of air. The best method of holding the battery is by using hooked bolts that catch on the battery handles and screw down tight. If the battery case is wet or if the inside of the battery box is wet, the moisture should be wiped away with a cloth slightly wet with ammonia water.

It is, of course, essential that the electrical conditions of charge and discharge be correct for the battery. These points are taken up in other parts of this book, but it should be noted that the dynamo should give such an output at fifteen miles an hour car speed that the battery is not being discharged with all lamps turned on. It should also be remembered that the demands on the system and on the battery are much greater in winter than in summer. The efficiency of the battery is much lower when cold than when warm, and the dynamo does not give an output as great as would be required for the extra lamp load imposed by the greater number of dark hours, and also by starting a cold engine under winter conditions. Therefore, the battery should have the very best of care during cold weather. Lamps should be used as economically as possible, and, if convenient, lower candlepower bulbs should be substituted in the lamps. The engine should be started by hand for the first time on cold mornings, and at all times the carburetor and ignition should be in such adjustment and condition that but a very few seconds' cranking with the motor will suffice to start the engine. Care of this kind will do more than anything else to insure satisfactory operation of the whole electrical system, because nothing else can do its work unless the battery is in good order and properly charged.

CHAPTER IV

LAMPS AND WIRING

One of the principal purposes of the whole electrical system is to furnish light, and the subject of lamps and their connections is an important one. The lighting parts that are most directly concerned are the bulbs and reflectors in the lamps, the wiring with its insulation and supports, the switches for turning the lamps on and off, and, in some cases, the protective devices, such as fuses and circuit breakers.

THE LAMPS

Bulbs.—A bulb is composed of a filament enclosed in a glass housing from which the air has been almost completely exhausted, and this glass part is carried on the metal base (Figure 41). Two kinds of filament are in use, tungsten and carbon, and two kinds of bulbs, one in which the exhausted air is not replaced, and another in which the air is replaced with nitrogen gas. The first kind of bulb is known as the vacuum type, the second is called a nitrogen bulb.

Tungsten filaments should be used exclusively because of their greater efficiency as compared with carbon. Depending on the candlepower, the tungsten filament will require from 0.95 watts for each candlepower up to 1.25, while the carbon bulb will take on an average of 2.5 watts for each candlepower of light. It is, therefore, poor economy to use carbon filament bulbs for any purpose. In making lamp calculations the following data may be used:

Bulbs up to 4 c.p.....1.2 watts per candlepower
6 c.p. to 10 c.p.......1.0 watts per candlepower
12 c.p. and above.... .95 watts per candlepower

Bulbs operating at their normal voltage will require an amperage sufficient to allow the specified consumption in watts. This will cause the bulb to give its full candlepower, and its useful life may be expected to reach from 200 to 300 hours of burning. If the voltage is less than normal, the bulb will not require its rated flow in amperes, and under these conditions the candlepower will be lower and the life longer.

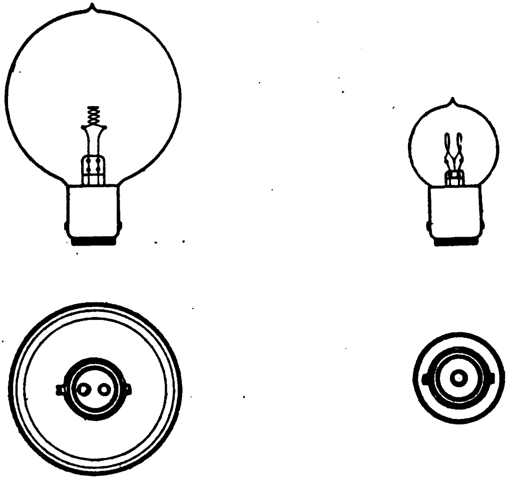


Figure 41.—Double-Contact and Single-Contact Lamp Bases.

Bulbs in common use range in voltage from 3 or $3\frac{1}{2}$ up to 21, depending on the number of cells in the battery with which they are used and their connection with each other. It is customary to use bulbs of a voltage one-sixth above what would be required on a basis of exactly two volts for each cell of the battery. Thus, with a three-cell battery, seven-volt bulbs will be used in place of six; with a twelve-volt battery, fourteen-volt bulbs will be used, while with an eighteen-volt battery, twenty-one-volt bulbs will be found. The three-volt bulbs are used in pairs on a six-volt battery, the two three-volt bulbs using the six volts of the battery just as one six-volt bulb would do.

Five bulb sizes are in use. The bulb size refers to the diameter through the glass part, and does not vary exactly according to the candlepower. Two, four and sometimes six candlepower bulbs are made of three-quarter inch diameter. Four, six and sometimes eight candlepower bulbs are one inch or one and one-quarter inches. Bulbs of larger candlepowers are made either one and one-half or two and one-sixteenth inches in diameter. In replacing old or broken bulbs with new ones, the replacement should be made with a bulb of the same diameter as the one removed, otherwise it will be necessary to refocus the lamp, and if too great a change is made in the size the refocusing cannot be done properly.

Bulb Bases and Sockets.—Four types of bulb base are in use; two, of the familiar screw type, are seldom found except in interior body work, while the other two, of the bayonet type, are in common use for all purposes. The bayonet type is often called the Ediswan socket, and makes use of a spring locking device that holds the bulb firmly in place against jarring and consequent loosening. (See Figure 9.)

The base for this type is cylindrical and carries two small projecting pins on the sides and directly opposite each other. The socket into which the base fits is also cylindrical, and of such proportions as to make a rather loose fit. Two slots are cut along the sides of the socket, and when the bulb base is placed in position, the projecting pins slide into these slots. At the bottom, the slots end in a small upturned notch so that the base pins will fit into the notches when the bulb is given a part of a turn. In the bottom of the socket are springs that press against the inner end of the base and keep the pins in place in the notches.

One kind of bayonet base carries a single electrical contact in the center of the bottom of the base, this contact coming against a contact spring or plunger in the socket when the bulb is in place. The current for the lamp is carried through the contact for one side of the circuit, while the connection for the other side of the circuit is completed through the metal of the base cylinder where it comes in contact with the metal of the socket. This is called a single contact base, and was primarily designed for use with the one-wire or grounded system of wiring in which the shell of the socket is attached to the metal of the car to carry the current for one side of the circuit.

Another kind of bayonet base has two contact points on the bottom of the bulb, both being insulated from the metal of the socket and from each other. The current for the lamp is carried in through one contact and out through the other, and there are two springs or plungers in the socket that make connection with the base contacts when the bulb is in place. This is called the double-contact base, and is used with the two-wire, or insulated return method of car wiring, in which both sides of the circuit are carried by insulated wire.

One of the screw types is called the candelabra base, and the other one, which is of smaller size, is called the miniature base. Their construction is similar to that used for house lighting work, a single contact carried in the center of the bottom of the base making connection with a spring in the bottom of the socket. The other side of the circuit is completed through the shell of the socket and of the base.

Lamp Care.—The light from the bulbs is directed toward the road by means of silver plated reflectors of parabolic shape or by reflectors made from silvered glass like a mirror. The glass reflectors are not found as commonly as the silvered metal ones, but give satisfactory service when used.

In order to reach the interior of the lamp for bulb renewal, cleaning or focusing, it is necessary to remove or swing to one side the glass cover placed over the front of the lamp. This cover may be held in place by hinges, although plain hinges are seldom used because the lamp should never be opened except when really necessary, and because of the danger that the bulbs will be taken out if left too easily accessible. Lamps are often made with pinned hinge joints on both sides, and it is then necessary to withdraw either one of the pins to allow the other side to act as a hinge.

The lamp covers or glasses are often held in place by screws and in some cases the screw-heads are made so that it is necessary to use a peculiar form of wrench that is furnished with the tool equipment of the car. A type of lamp in rather common use holds the fronts in place by means of a spring lock, and with the cover in position nothing about the outside of the lamp gives any indication as to the method of fastening. This type is handled by pressing in on the rim of the cover and at the same time turning it to the left, when the whole front of the lamp will come off. Great care should be used to prevent dirt or moisture from touching the reflector while the cover is removed.

Should the reflectors become dirty or tarnished, they may be carefully cleaned and brightened, although the surface of the reflector will be somewhat damaged every time it is touched, no matter how careful the work is done. Dust may be removed from the reflectors by blowing it out or, if it does not yield to this treatment, a stream of clean cold water at very low pressure may be used. If water is used the reflectors must be allowed to dry by the air alone, and must not be wiped off.

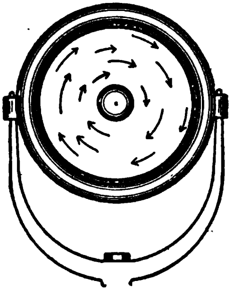


Figure 42.—Method of Cleaning Lamp Reflectors.

For cleaning the silvered surface no liquid except alcohol is ever used. This is applied with a clean, soft chamois skin. The chamois must be held so that there are no wrinkles, and the reflector is then wiped over the whole surface by using a rotary motion (Figure 42), starting at the bulb socket and gradually working out toward the front of the lamp. The cleaning is sometimes done by wiping from front to back, but in either case the pressure should be very light and even. Rubbing back and forth will surely scratch the surface of the reflector.

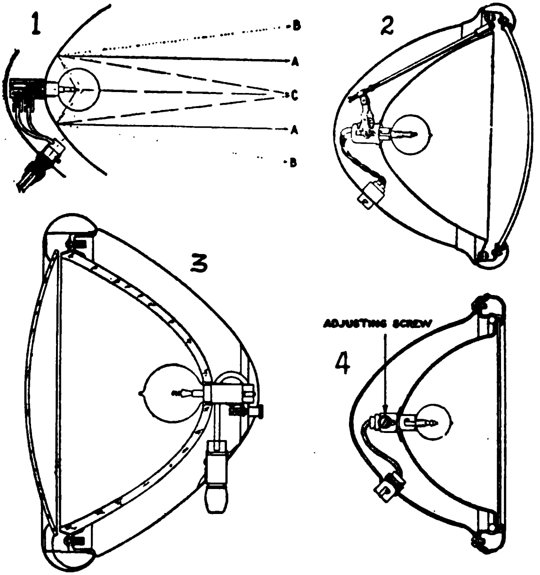


Figure 43.—Lamp Focusing Methods. 1—Light Rays Follow Lines *A* with Proper Focus; with Improper Adjustment They Follow Lines *B* or *C*. 2—Focusing Screw at Upper Front Edge of Reflector. 3—Focusing Screw at Rear of Lamp Case. 4—Adjusting Screw in Lamp Socket.

If the silvered surface is tarnished it may be polished by moistening the chamois with alcohol and then applying a small quantity of jeweler's rouge. The wiping should then be done in the same way as for cleaning. After the coating of oxide has been removed, the polish is completed with more rouge placed on a dry chamois skin.

In order that the lamps may be used to the best advantage, the bulbs must be properly focused and the lamps must be in such a position on their brackets that the rays of light are thrown on the road at the proper point. It will generally be best to get the bulbs in approximately proper focus and then place the lamps in proper alignment.

The bulbs are focused by moving them forward or back in the case so that their filaments will come into a different relation to the curved surface of the reflector. (See Figure 43.) Many lamps are made so that the bulb position may be changed by turning a small screwhead or nut that will be exposed when the front of the lamp is out of the way. The focusing screw is usually in the center of the upper edge of the rim, and by turning it one way or the other, the bulb is moved forward and back. Bulbs are also held in a socket that may be slid bodily in or out of the reflector by first turning it slightly. When the bulb and socket have been moved to the desired position, the socket will lock in place when released. Other lamps hold the socket in a cylindrical casing and lock it in place with a clamp or setscrew. This screw can be reached from the rear side of the reflector, and with it loosened, the socket may be pushed back and forth.

One lamp should be focused at a time. This may be done by turning the current off from one of them or by covering one with a thick cloth or coat. The focusing must be done in a dark room or on a dark road, preferably on the road. The car should be placed so that no street lights are near enough to cast a light near the car, because they will affect the adjustment. The bulb should be moved back and forth until the light on the road is clean and free from rings or black spots. If the work is done in a room, the light may be directed against a wall and the bulb moved until a clean and clear ring of light is thrown straight ahead. It will always be best to drive the car on the road before deciding that the adjustments are correct. It will often be found that focusing which is apparently right with the car standing still will not be the best that may be secured for driving.

After each of the lamps has been focused as described, the fronts should be replaced and the lamp casings moved on their brackets, or the brackets themselves moved so that the light from each lamp strikes the road at the point desired by the driver. The best method of changing the lamp position will be apparent upon examination. Some cars are provided with adjustments for this purpose and others have no means except to bend the brackets.

WIRING

This subject immediately suggests the two principal systems that are used for carrying the positive and negative sides of the circuits, that is, the one-wire, or grounded return, method, and the two-wire, or insulated return, method. The wiring applies as much to the charging system as to the lighting, and the information that follows will take both systems into account.

One-Wire System.—This construction makes use of the fact that the metal of which the chassis parts are made is an excellent conductor, and because of the large sectional areas in use as compared to the sizes of wire, a conductor of very low electrical resistance.

In place of the older method of carrying both sides of the circuits through copper wires insulated from metal parts of the car, the one-wire system attaches one side of the battery, one side of the lamps and one side of each of the other electrical units included, to the frame, or to other metal parts of the car that are in electrical contact with the frame. (See Figure 44.) From the remaining side of the battery wires are run through the switches and other connecting parts to the lamps and whatever other units are included in the one-wire system. Any part that is thus attached to the metal of the car parts is said to be grounded, and this system is oftentimes called the ground return system.

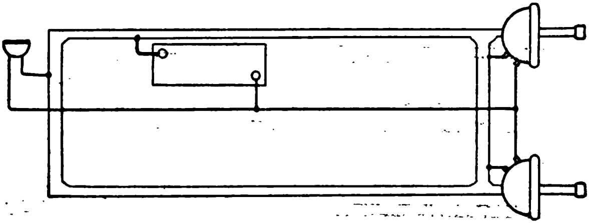


Figure 44.—One-Wire Connections.

Theoretically it would be possible to eliminate one-half of the wire that would be required with a two-wire system, but this is not true in practice, because it is not possible to place the battery, dynamo and other units in such a way that they may always be attached directly to the metal work, or to "ground." This is especially true of body lights and of side and dash lamps that are carried on wooden parts of the car. The saving from the standpoint of wire used is in practice between one-third and one-half, the exact amount depending on the design and mountings used.

The principal advantage of the one-wire system, outside of the evident advantage of saving in wire, is the greater ease of providing heavier insulation. It will be realized that, in a lamp socket and bulb base, for instance, the room that may be utilized is quite limited, and if but one conductor must be insulated, the covering and protection for this one side of the circuit may be made heavier than were it necessary to handle two insulated leads for each lamp.

The same advantage applies in a similar way to the other units, and because of the saving in material and the greater ease of manufacture and installation, the one-wire system has gained steadily at the expense of the two-wire system since its first adoption.

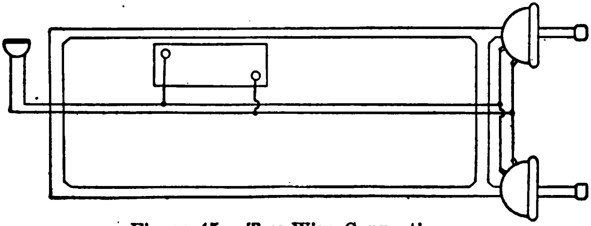


Figure 45.—Two-Wire Connections.

Care must be used with this system of wiring to see that the connections of the copper wires from the various units are securely fastened to the metal of the car and that the contact surfaces are perfectly clean and protected from the action of air and moisture.

Two-Wire System.—This method of wiring does not make use of the metal work of the car as a conductor, both sides of the circuit being carried by insulated copper cables at all points (Figure 45). The most apparent advantage of this method is in the lessened danger of accidental short circuits from broken insulation. With both positive and negative conductors insulated it would be necessary to break through the insulation on both sides before any leakage of current could take place. Even though the positive wires were bared, no current could flow from positive to negative sides of the battery unless the negative lines were also bared at a point that would allow contact between positive and negative. Likewise, the negative cables might be stripped of their insulation at one or more points without leakage occurring unless the positives were also stripped at the points that would touch the negatives.

With the one-wire system either the positive or negative side, depending on which one is grounded, will always be without insulation, and a failure of the insulation on the other side of the circuit at any point where the cable can come into contact with the metal parts of the car will result in a short circuit. This may be guarded against to a certain extent by the heavier insulation possible with the one-wire system.

Because of the possibility of short circuits with the one-wire method, it is customary to use fuses that will burn out or circuit breakers that will open with an abnormal flow of current through the wires. By thus breaking the circuit in trouble, the danger of completely discharging the battery is eliminated. With the two-wire system fuses and circuit breakers are not so commonly used, although their adoption or omission depends entirely on the ideas of the designer.

Another advantage of the two-wire system is found in the absence of connections between copper conductors and the steel or aluminum of the metal parts of the car. This form of joint is not as easy to make and is not of such low resistance as one between copper and copper. Any joint between two different metals is subject to an electrical action that will result in corrosion and high resistance unless the joint is properly protected. The grounding connections between the lamps and their brackets and between the electrical parts mounted on the engine and the metal of the engine must be well made and carefully watched to avoid looseness and dirty contacts with the one-wire system, while the two-wire method requires only that the joints be clean and tight between surfaces that are both copper.

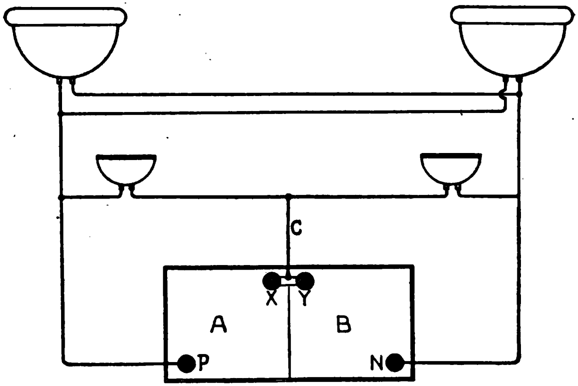


Figure 46.—Three-Wire System with Evenly Divided Battery.

Three-Wire System.—This class of wiring designates a method by which two different voltages may be secured on two different circuits with the use of but three wires for both circuits in place of four, as would ordinarily be required. It may be used with either the grounded or insulated return wires, inasmuch as it really means three conductors, which may be of wire or of the metal of the car parts.

The connections for one kind of three-wire system are shown in Figure 46. The battery is composed of two separate sections, *A* and *B*, which, for purposes of illustration, may be considered as of six volts each. The two sections are connected at their terminals, *X* and *Y*, *X* being negative and *Y* positive. The remaining terminals are shown at *P* and *N*, *P* being positive and *N* negative. Between the terminals *P* and *N* twelve volts may be secured, inasmuch as both sections are working together and adding their pressures. The head lamps are connected so that each bulb is attached to battery terminal *P* and to *N*, and they will therefore operate at twelve volts pressure.

The side lamps are connected in such a way that the left-hand lamp is attached between positive terminal *P* and negative terminal *X*, using one section of the battery and six volts' pressure. The right-hand side lamp is attached between the negative terminal *N* and the positive terminal *Y* on the other section of the battery, and also at six volts pressure. The terminal formed by joining *X* and *Y* is called the neutral terminal, and the wire *C* is called the neutral wire.

It will be seen that the removal of the wire *C* would leave the two side lamps in series with each other, so that all the current passing through one of them would also have to pass through the other. With the wire *C* removed, the two lamps would be connected in series between the battery terminals *P* and *N*, and would receive twelve volts. Two six-volt lamps will operate on a twelve-volt circuit when connected in series, and this rule holds true for any combination of voltages in which the battery or circuit voltage is equal to the number of lamps multiplied by the voltage of each lamp. The lamps must all be of the same voltage, and this method would not always operate with one six-volt and one twelve-volt lamp on an eighteen-volt circuit.

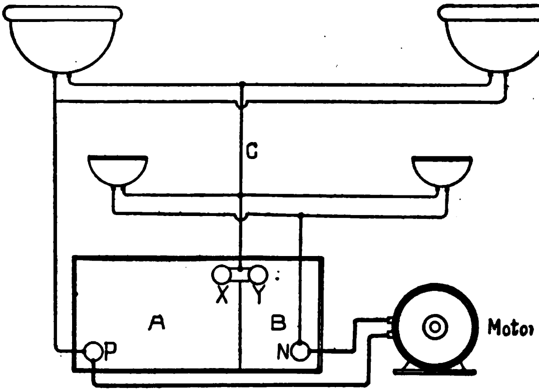


Figure 47.—Three-Wire System with Two-Lamp Voltages and Higher Voltage for Starting Motor.

The advantage of the neutral wire *C*, in this case, would be that either one of the side lamps could be operated independently of the other by allowing the neutral wire to carry the side lamp current. With both lamps turned on, the neutral wire is dead, and the current flows from battery terminal *P* to terminal *N*.

Another three-wire arrangement is shown in Figure 47. In this case the battery is divided into two sections of unequal size, section *A* being six cells of twelve volts, and section *B* of three cells and six volts. The sections are connected with each other between terminals *X* and *Y*. This arrangement allows of three different voltages. The starting motor is connected between the terminals *P* and *N*, and receives the full voltage of both sections, which will be eighteen. The head lamps are connected between the positive terminal *P* and the negative terminal *X*, and therefore operate with twelve volts from the battery section *A*. The side lamps are connected between the negative terminal *N* and the positive terminal *Y*, and therefore operate at six volts on the battery section *B*. The wire *C* is in this case neutral and acts for either the side or head lamp circuit. Were the wire *C* to be removed from Figure 47, it would leave the twelve-volt head lamps in series with the six-volt side lamps on an eighteen-volt battery. As stated before, this should not be done, because, except under one condition, either the head lamps or the side lamps would not burn. The one condition under which both sets would burn with the neutral wire removed is with both sets of such candlepower that they would require exactly the same amperage to light them. With lamps in series, the flow or amperage is the same through all parts of the circuit, and the set that takes the least amperage will govern the flow through the circuit, with the result that the lamps that require a greater flow will not light up at all, or but dimly.

Wires.—The wires may be considered as consisting of the copper which forms the conductor for the current, of the insulation covering the conductor, and of the terminal connections that serve to make the necessary attachments between the various wires and between the wires and the electrical units on the car.

Of the three parts, the last will be found most important from the standpoint of upkeep. The greatest trouble is experienced in making and keeping the terminal connections tight and clean at all times. Unfortunately it is not possible to make permanent connections, because of the necessity that may arise for removing some of the wiring or some of the instruments. It will, therefore, be necessary to use the greatest care at this point if trouble is to be avoided.

The size of conductor that should be used at any particular point in the installation depends on the amperage and voltage that is to be carried and on the length that the current must be taken between the units. Conductors are usually measured by wire gauge sizes, in which the larger numbers indicate the small sizes of wire, while low numbers indicate large sizes of wire. Gauge sizes (Brown & Sharpe standard) are found from No. 16 (about one-twentieth inch in diameter) to No. 00 (nearly three-eighths inch in diameter). Sizes from No. 3 up to No. 00 are used for the starting circuits, while sizes from No. 8 to No. 16 are for lighting and charging circuits. Should the wire size be too small for the work it is called upon to do, the resistance will be so great as to cause an abnormal drop in voltage and improper operation of the units supplied by the defective circuit.

The insulation of the wire is oftentimes called upon to do double duty in giving protection against leakage of the current, and also in protecting the conductor against mechanical injury. Electrical protection is usually cared for by various compounds of rubber that surround the conductor with a protective coating of sufficient thickness to resist the voltage in use plus a liberal margin for safety. Various means are used to give mechanical protection, the commonest being a covering of fabric woven or braided over the electrical insulation of the wire. In many installations the mechanical protection is given by covering the wire with a flexible housing of braided brass or very thin steel. This type is called armored cable, and gives excellent results in use.

The wiring should be firmly fastened to the parts of the car near which it runs, and these fastenings should be made with screwed joints of some form. The wires should never be fastened in such a way that the covering will come into contact with corners or sharp edges of metal, because the final result will be breakage or short circuits. In case it is necessary to run the wiring into positions where it will be exposed to the possible action of grease, oil or water, it should have a weatherproof coating of some form. If armored cable is not used it is general practice to use metal tubing of flexible construction, or else to use conduit. Should neither of these protecting coverings be supplied, the needed protection may be given by covering the exposed portion of the wiring with ordinary circular loom, such as is used in stationary electrical construction.

No wire should be used that is not designed for starting, lighting or ignition work. This means that the conductor must be composed of a cable made up from a large number of fine wire strands and known as flexible or stranded cable. The insulation must be designed for this class of work, and under no conditions is it permissible to use substitutes like flexible lamp cord, such as is found in house wiring.

All wire ends should be fitted with metal terminals

(Figure 48) of special form, designed to make a good electrical and mechanical connection with the various units. These terminals should always be soldered to the ends of the wire so that there is no chance of corrosion or looseness. In case it is necessary to attach a wire and no terminal can be fitted, the work may be done by baring the end for a short distance and, after bending the end into a loop, dipping it into solder so that it is made solid enough to prevent loose strands from forming. The loop should then be placed on its connection in such position that it wraps around in a right-hand direction, and so that tightening of the screws will tend to coil the wire closer around the terminal post in place of unwrapping it.

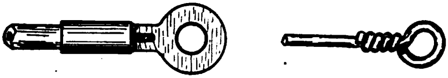


Figure 48.—Wire Terminals.

After wiring has been attached to the terminal posts, the fastening screws should be made tight and should preferably be locked in position with wire or by soldering. While this method makes it harder to remove the parts, it also prevents the commonest of all troubles, looseness.

SWITCHES

The amperage or current that is carried by the circuits of the automobile lighting system is considerably greater than that carried in the ordinary house lighting system. The amount of light in candlepower may be no greater or it may be about the same. This would mean that the power in watts would be about the same, and because of the low voltages in use with car lighting systems, the amperage must be correspondingly higher. The contact surfaces of lighting switches for use on cars must be made large and of material that will stand the sparks that are formed when the circuits are broken.

Many types of separate lighting switches are in common use. One of these types carries two small push-buttons on its face-plate, one button serving to close the circuit and the other to open it. They are mounted at opposite ends of a pivoted arm so that pushing one of them in will cause the other one to come out. The contacts are actuated by spring-operated arms so that the circuit is broken quickly enough to prevent excessive arcing. Another type very similar in construction makes use of but one button, this usually being pulled out to close the circuit and turn on the lights and pushed in to turn them off. One switch is provided for each circuit that is to be controlled, and the switches are usually assembled with the proper number attached to one face-plate that appears within reach of the driver.

A third type is that known as the rotary snap switch (Figure 49). This is built on the same principle as the switches in common use for house lighting, with which the switch button is always turned to the right to turn the lamps off if they are burning and to turn them on if they are unlighted. These switches for automobile work are made so that the several combinations of lights are given by successive quarter turns or sixth turns of the button. A combination in common use for the four quarters would be as follows: All Off. Head Lights Dim, Tail Light Bright. All Lights Bright. Side Lights and

Tail Light On. The next quarter would then bring the switch back to the "All Off" position.

Many combination switches are in use that care for the lighting, starting and ignition circuits by bringing two of them or all three to the one-switch unit. The combination switch that serves for lighting and ignition is in most common use, this type usually being fitted with separate buttons or levers for the two functions. This makes it in reality two switches of any suitable form carried in one housing. Switches are also in use that have but one lever or button for both lighting and ignition. With the switch button in place, the ignition is turned on, and with the button moved into various positions the different lighting combinations are secured. Removal of the button with any lighting combination in use will then stop the ignition, but will allow the lights to remain lighted as with the button in place.

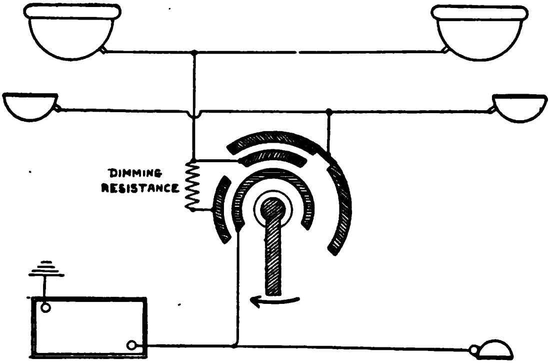


Figure 49.—Rotary Lighting Switch Construction.

Combined starting and ignition switches are in general use with motor-dynamos that do not make use of an automatic cut-out. (See Figures 59 and 60.) These switches usually have three positions, although they are also made with but two changes, "On" and "Off." With the three-position switch the points are marked "Off," "Neutral" or "Idle," and "Start" or "Run." In the "Off" position the ignition is inoperative and the motor-dynamo is disconnected from the battery. In the "Start," or "Run," position, the ignition is turned on and the battery current is allowed to flow to the motor-dynamo, making it act as a starting motor. If the switch is left in this position the motor-dynamo will act as a dynamo when the engine speed is sufficiently high. In the "Neutral," or "Idle," position, the ignition is turned on, but the motor-dynamo is disconnected from the battery, so that no starting motor action will take place. Some switches have a "Neutral" position in which starting motor action can take place, but arranged in such a way that the field circuit for the dynamo is open and the unit cannot charge the battery. This last arrangement is designed to prevent excessive battery charge on long runs, such as in touring.

Combined starting, lighting and ignition switches are also made in various forms. They may be simply a collection of the separate switch units in one case, or they may be designed to produce starting, lighting or ignition by movement of one lever or button in different directions. Such switches are marked on the face-plate so that the operator need only follow the directions to secure the desired result.

FUSES

A fuse consists principally of a short length of wire of such a composition that it will carry a certain amperage with very little resistance, but when this amperage is exceeded will rapidly rise in temperature to such a point that it will melt and thus break its connection in the circuit and prevent further flow of current. Fuses are used in either the lighting or charging circuit and oftentimes in both. The wire may or may not be enclosed inside of a small tube. When unenclosed they are called open-fuse links, or simply fuse wire. This form is not safe to use around a car because of the danger of fire from the exposed flash should the fuse burn out. Enclosed fuses are called cartridge fuses and may be surrounded with a tube of fibre or one of glass (Figure 50). With glass-enclosed fuses it is very easy to discover when one has been burned out by looking through the glass. With fibre covering, burning of the fuse causes a small blackened spot to appear at some point along the tube, usually at the center. Fuses may always be tested by attempting to pass current through them and at the same time through a lamp or meter of some kind. Failure to secure a flow indicates a blown fuse, and it will be necessary to replace that one with a new one. Their cost is so low that there is no economy in attempting to renew the fusible wire.

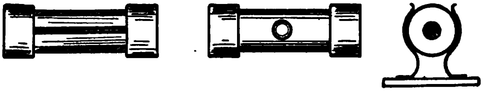


Figure 50.—Glass and Fibre-Bodied Cartridge-Fuses.

Fuses are always rated according to the amperage they will carry without burning out. The voltage need not be considered in their selection. The proper size to use will, of course, vary with the voltage and candlepower of the lamps supplied or with the flow required through the charging circuit, field circuit or other path of current in which they are placed. In the absence of definite instructions the following sizes may be used. These are calculated for a six-volt system. Higher voltages will require a smaller amperage and fuses of lower rating.

Head lamps	15-ampere
Side lamps only	5- to 8-ampere
Tail and dash lamps	5-ampere
All lamps	20-ampere
Horn	15-ampere
Dynamo field fuses	3- to 10-ampere
Charging circuit fuses	20- to 45-ampere

A fuse should never be replaced with one of a larger size than that specified by the car or equipment manufacturer, and should never be replaced with wire or nails. Fuses are only used at points through which an excessive flow of current may occur, and which will cause more or less serious damage when it does occur. Replacement with such substitutes in the lamp lines may result in burning out all the bulbs affected; in the dynamo field circuits the result will be burned-out dynamo field windings, and in the charging circuits the result will probably be a ruined battery.

Cartridge fuses are held in spring clips at each end. These clips should be set so that they hold the fuse without looseness, and the contact surfaces between fuse and clip must be clean and bright. A particle of dust at this point will prevent any flow of current. Trouble may be experienced with the fastenings between fuse clips and their bases or between the clip and the wire end to which it is attached. These points should be examined in case of an open circuit or a greatly diminished flow through a circuit in which fuses are used. In case the ends of a cartridge fuse or the surfaces of the fuse clips are found dirty or corroded they should be cleaned and brightened with sandpaper.

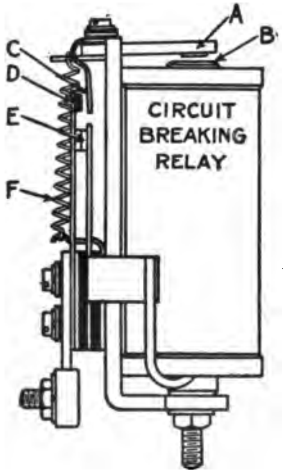


Figure 51.—Lighting System Circuit Breaker (Delco)
A—Magnet Armature.
B—End of Magnet Core.
C—Arm Attached to Armature.
D—Bumper on Movable Contact Arm.
E—Circuit Opening Contacts.
F—Spring.

CIRCUIT BREAKERS

The disadvantage in the use of fuses for protection is that spare ones of the right size must be at hand for purposes of replacement. Unless the right fuse can be easily obtained, it is a great temptation to replace it with a length of wire. To obviate this difficulty a magnetic circuit breaker is often used which rapidly opens and closes the circuit because of excessive amperage. (See Figure 51.) These circuit breakers consist of an electromagnet around which passes the current flowing in the circuit. Carried at a point near enough the magnet core to be influenced by it is a small armature, and to this armature is attached, either directly or by springs, one contact through which the current flows on its way around the magnet and through the circuit. A stationary contact is mounted so that it touches the movable one, and as long as they remain together the current flow can continue.

Should the amperage passing around the magnet become too great for safety, the armature is attracted and the contacts are separated, because the magnetism produced will overcome the strength of the spring that normally holds the contacts together. The circuit breaker contacts may then remain apart or come together again, depending on the design. With no other parts than those described, the contacts will immediately come together after they once open, because the flow around the magnet is stopped when they separate. With no flow around the magnet the spring will again cause the circuit to close, and the action will be repeated rapidly, with a continuous clicking or buzzing noise, until the cause of the excessive flow is eliminated.

Other forms of circuit breakers are so constructed that the movable arm is caught and held by a latch so that the circuit is not again closed after once being opened. A handle or trigger is arranged so that the driver may release the latch and allow the breaker to return to its operative position. The adjustment of a circuit breaker spring should never be changed, because this would have the same effect as if fuses were replaced with others of higher capacity. The tension is just right for the current to be carried, and any increase will probably result in damage.

LAMP DIMMING

It is often desirable to reduce the amount of light or candlepower of the head lamps to prevent glare being thrown in the eyes of drivers of approaching cars. This dimming is required by law in many parts of the country, and must be provided for in some way or other on all cars. The method that has been used for the longest time is that of providing additional lamp bulbs of smaller candlepower than those used for the large head lamps. These small bulbs are often called ''dimmer'' bulbs or ''pilot'' bulbs, and may be carried inside of the head lamp housing or in a small extension from some point on the lamp housing. Additional circuits are then arranged so that these small bulbs may be lighted when the large ones are turned off, and the light is thus cut down to the proper point.

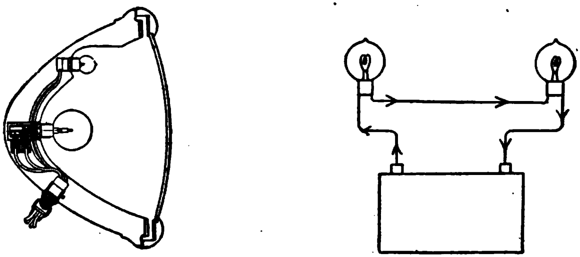


Figure 52.—Dimmer, Marker or Pilot Bulb in Headlamp (Left). Connections for Series System of Lamp Dimming (Right).

Two other methods are in use, both of which cut down the flow of current through the large head-lamp bulbs to such an extent that the candlepower is much reduced. One method acts to place the two head-lamp bulbs in series with each other across the terminals of the battery (Figure 52). The resistance of the two lamps in series is twice as great as that of either one of them alone, and the flow of current through them is therefore reduced to half of its former value. Inasmuch as this means a reduction of the watts consumed in each lamp, the candlepower, which depends on the watts, is reduced in proportion. Switches are arranged on the dash, or at any convenient point, so that the driver may place the lamps in parallel for bright lighting or in series for dimming. With the parallel connection each lamp bulb is connected directly to the two battery terminals so that each bulb receives the full battery voltage and takes its normal amperage. The arrangement is usually called series-parallel dimming.

Another method commonly used does not require the additional wiring called for by the series-parallel connection, and is, therefore, more easily applied.

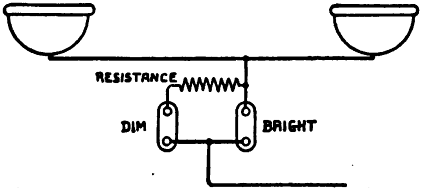


Figure 53.—Switch Connections for Resistance System of Lamp Dimming.

This method consists of a length of wire of high resistance that may be placed in the lamp circuit or withdrawn from the circuit, according to the driver's use of the switches. (See Figure 53.) The added resistance of this wire prevents the full amperage from reaching the lamp bulbs, and they burn less brilliantly. The extent of the dimming may be controlled by changing the length of resistance wire placed in the circuit, and with this form in use the lights may be made brighter by connecting two or more coils of the dimming resistance together with copper wire so that the lamp current will flow through the copper wire in place of passing through the resistance in the short-circuited coils.

CHAPTER V

CONTROLLING DEVICES

CUT-OUTS

All electrical equipments that include a dynamo for charging the battery must have a switch of some kind for disconnecting these two units from each other while the engine is idle or running at speeds so low that the voltage generated is not sufficient to cause charging to take place. But three principal types are in use, one being operated automatically by an electromagnet, another by a centrifugal weight, and the third being operated manually by the driver of the car. The switch of the third type is so connected that it will be operated with the starting switch or with the ignition switch, and thus the danger of leaving the charging circuit closed is avoided.

Electromagnetic Types.—The type of cut-out in most general use makes use of an electromagnet whose windings are connected between the dynamo brushes at all times. This magnet consists of a core of soft iron around which is wound a coil of many turns of fine wire. One end of this coil is connected electrically to one side of the dynamo and the other end of the fine wire coil is connected electrically to the other side of the dynamo. The magnet winding is, therefore, in shunt with the charging lines from the dynamo, and is called the shunt winding of the cut-out. The proper operation of the cut-out depends on the action of a second coil of wire being added to the shunt coil. This second coil is so connected between the dynamo and the battery that all of the current passing through one side of the circuit from the dynamo during the time the cut-out contacts are closed will flow around this second coil. This winding is called the series coil of the cut-out, and the necessity for its presence will be considered after the action of the shunt winding is explained.

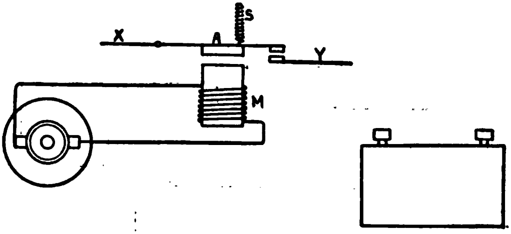


Figure 54.—Principle of the Magnetic Cut-Out.

Figure 54 illustrates the principle upon which the cut-out switch is closed. The winding of the magnet *M* is connected to the dynamo brushes as shown. The wire of which this winding is composed is so small and there is such a great length of it that the resistance through the coil is great enough to prevent more than a very slight flow of current passing through it. This avoids too great a loss of dynamo current through the cut-out itself. Mounted at some point on a hinged or spring arm above the core of the magnet is the magnet armature *A*, and when the magnetism in the cut-out magnet is great enough in strength, this armature will be attracted to the end of the magnet, overcoming the strength of the spring *S*. This will close the contacts

C, and a circuit completed through the wires *X* and *Y* will be closed by the movement of the cut-out armature.

With the dynamo idle there will be no pressure or voltage between its brushes and consequently no current will flow through the magnet winding. As soon as the dynamo starts to revolve some voltage will be generated, and this voltage will cause a flow of current through the cut-out shunt winding. The tension of the cut-out spring *S* is set at a point that holds the armature *A* away from the magnet, and consequently holds the contacts *C* apart until the dynamo voltage has risen above the voltage of the battery to which the dynamo is attached. When the dynamo is operating at a speed high enough to cause a voltage in excess of that of the battery the contacts *C* will be brought together, and the circuit through wires *X* and *Y* will be completed.

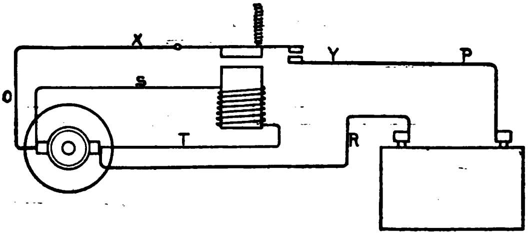


Figure 55.—Elementary Magnetic Cut-Out with Battery Connections.

In Figure 55 the dynamo is shown connected to the battery. The wire *O* has been connected from one dynamo brush to the wire *X* and the wire *P* has been connected from the wire *Y* to one terminal of the battery. The other dynamo brush is connected to the remaining terminal of the battery through the wire *R*. Closing the contacts *C* will now connect the dynamo and battery, and inasmuch as the voltage of the dynamo is above that of the battery before the contacts close, the battery will be charged by current from the dynamo.

The connections and arrangement shown in Figure 55 would be satisfactory for closing the circuit between battery and dynamo, but would not open it properly in practice. Theoretically, the spring *S* would pull the contacts apart when the dynamo voltage falls to a point below that necessary to hold the contacts together. In actual operation the following action takes place: At the instant when the dynamo voltage becomes just equal to that of the battery as the dynamo speed falls, there will be no flow through the cut-out shunt coil. If this condition lasted for any appreciable time the contacts would open, but the falling dynamo speed immediately allows the voltage to become less than that of the battery, and before the contacts can open a flow of current starts from the battery to the dynamo through the closed contacts *C* and the wires *P, Y, X, O* and *R*, because the battery voltage is above that of the dynamo. A part of this flow will pass through the wires *S* and *T* and through the cut-out winding, thus holding the contacts together and allowing the battery to discharge through the dynamo. The cut-out remains closed at the comparatively low voltage of the battery because of the fact that it does not take as much magnet strength to hold the armature down as to draw it down across the air gap in the first place.

To overcome the fault just outlined, the connections shown in Figure 56 are used, this being the method actually used. The wire *S* has been combined with the wire *O* because both of them ran from the left-hand brush to the cut-out. The connection is completed from the end of *O* through the shunt coil of the cut-out just as it was completed from the end of *S* in Figure 55. The wires *T* and *R* have been combined into the wire *R* up to the cut-out and the current that has passed through the shunt coil of the cut-out returns to the dynamo through wire *R*. The shunt coil therefore closes the contacts just as it did before.

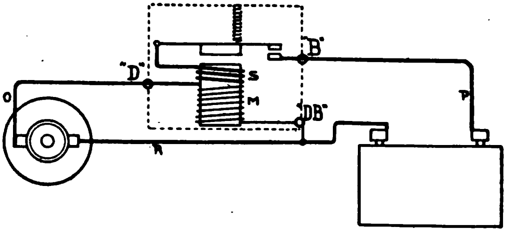


Figure 56.—Complete Connections for Electromagnetic Cut-Out.

The current from the dynamo that passes to the battery through the closed contacts now enters the cut-out at the terminal marked *D*, and flows around the additional coil *S* on the cut-out magnet, then to the contacts and from the terminal *B* through the wire *P* to the battery. The flow through the two coils on the magnet is in the same direction and the strength of the magnet is increased after the contacts close. This effect is, however, incidental. The current that has passed through the battery then returns to the dynamo through the wire *R*, passing by the cut-out terminal *DB* and flowing through *R* with the current that has passed through the shunt winding of the cut-out.

Now consider what happens when the dynamo voltage falls below that of the battery. Flow from the battery will take place just as soon as the dynamo voltage is low enough, but this flow must pass around the cut-out coil *S* in a direction opposite to its direction during charge. Part of this current will also pass through the lower shunt coil just as it did before, but the two coils now oppose each other because the flow of current is in different directions through them and the strength of the magnet will be completely destroyed as soon as the battery discharge through the coil *S* becomes great enough to overcome the strength of the coil *M*. At this time the contacts will be opened by the action of the spring and further discharge from the battery will be prevented. For the reason outlined, there should always be a slight discharge from the battery just before a cut-out of this type opens.

The second coil marked *S* and placed in series between dynamo and battery has another effect that is of importance. It will be realized that a cut-out having only the shunt coil would close and open at the same dynamo voltage. That is, if it closed against the spring tension at seven volts, it would reopen under the effect of the spring at seven volts. Should the car be driven at such a speed that exactly seven volts, or any other voltage corresponding to the spring tension, were to be generated, the cut-out would open and close continuously with damage to the contacts from the excessive hammering and sparking. With the series coil in use this action is prevented for the following reason: The cut-out closes under the action of the shunt coil acting alone, because the series coil carries no current until the contacts close. This will make the closing point come exactly when the strength of the shunt coil alone is sufficient to overcome the spring tension. After the contacts are closed the series coil adds its strength to that of the shunt and the strength of the magnet is increased. If now the dynamo voltage falls to the point at which the cut-out closed, it will not reopen because the magnet is stronger than when closing took place. The contacts will therefore stay closed until the combined strength of both coils is as low as the strength of the shunt coil alone when closing took place. In practice the cut-out should stay closed until the speed of the car is about two miles per hour below the speed of closing, that is, the speed at which the contacts will reopen will be about two miles per hour less than the speed at which they close. This prevents rapid opening and closing at some critical speed of the dynamo and car.

As stated, the connections shown in Figure 56 are those generally used. Separately mounted cut-outs of this type usually have three terminals; one, *D*, leading to the dynamo only; another one, *B*, leading to the battery only; and the third one, *DB*, being attached to both dynamo and battery.

The most common practice places both windings on one core as shown and explained. In some cases, however, two separate magnets are used, one carrying the series coil and the other carrying the shunt winding. Other types use two cores with part of each coil on each of the cores. These two cores, with either arrangement of windings, may be placed side by side or one above the other. With some systems the arm that carries the movable cut-out contact also carries one or two of the magnets. Such a method is used with Adlake equipment, there being two sets of magnets, one set stationary and the other movable. The movable set carries one contact and is attracted to the stationary set which is on top. The weight of the lower movable set is depended on to open the contacts and no spring is used.

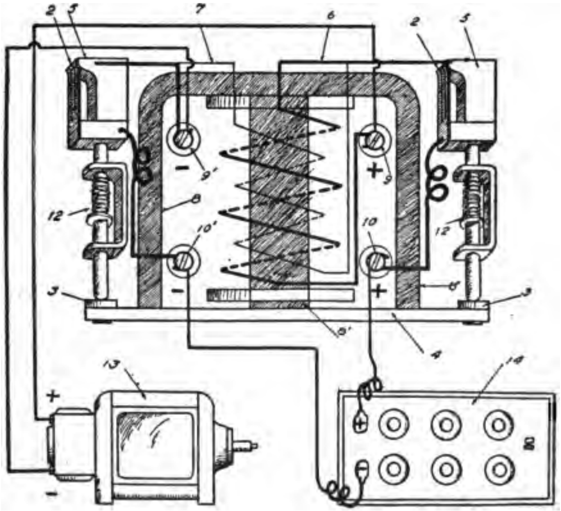


Figure 57.—Cut-Out to Break Both Sides of Circuit (Leece-Neville).

1—Battery Leads.
2—Movable Contacts.
3—Bumpers on Magnet Armature.
4—Magnet Armature.
5—Stationary Contacts.
6—Series Magnet Winding.
7—Shunt Magnet Winding.
8—Magnet Pole Pieces.
9—Terminals for Dynamo Leads.
10—Terminals for Battery Leads.
12—Springs for Plungers.
13—Dynamo.
14—Battery.

Cut-outs are sometimes made with two sets of contacts, one set being on the positive side of the charging circuit and the other set on the negative side. This type of cut-out will have four terminals, as shown in Figure 57. Four terminal instruments have been used with Leece-Neville and with Wagner systems.

It will be realized that a small flow of current is passing through the cut-out when the contacts open, this being the current that is passing from the battery through the series coil and dynamo and also that passing through the shunt coil. Breaking any circuit through which current is flowing will cause a spark and this spark is intensified when, as in this case, a coil of wire is included in the circuit. To prevent this sparking from causing damage to the contacts the construction shown in Figure 58 is often used. The two contacts are shown at *A* and *B*. Contacts *A* are made from carbon or any other material that is a fairly good electrical conductor and that is not easily affected by sparking. The upper or movable contact of the pair marked *A* is carried on a small flexible extension of the main cut-out arm and the contacts of this pair are closer together than the pair marked *B*. Both of the upper contacts move at the same time when the cut-out armature is attracted to the magnet, but the pair marked *A* will close before those marked *B* and when the armature is released by the magnet

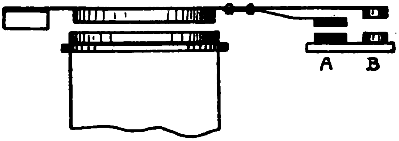


Figure 58.—Double Contacts for Cut-out. A—High Resistance Contacts to Take Spark. B—Low Resistance Contacts for Charging Current.

they will open before those marked *B* open. Contacts *B* are those depended on to carry the bulk of the current and they are made from metal of low resistance which would be damaged by excessive sparking.

The action is as follows: The contacts *A* close first, but as the armature is attracted further, contacts *B* will also close because the flexible arm carrying the upper contact *A* will bend slightly. With both pairs of contacts together the current flows through both of them, but most of it passes through the contacts *B*. When the cut-out opens, the contacts *B* separate first, but as current can still flow through contacts *A*, no spark is produced at *B* because the circuit has not been completely broken. As the armature moves away from the magnet to the full distance, the contacts *A* also open and the spark takes place between them. Because of their higher resistance the current flow has already been reduced to such a point that the spark that does take place is not so severe as if the circuit had been broken at its full strength.

Cut-out Adjustment.—The time, or dynamo speed, at which an electromagnetic cut-out will operate depends on two adjustments. One of these is the tension of the spring when a spring is used, and the other is the distance between the magnet core and the armature of the magnet. With increased spring tension the voltage, and consequently the dynamo speed, required will be increased. With an increased air gap between the magnet core and its armature the voltage and dynamo speed necessary to close the contacts will also be increased. Making the spring tension less or decreasing the air gap will lower the dynamo and car speed at which the cut-out closes. Increasing the spring tension or widening the air gap will raise the dynamo and car speed of cut-out closing. Some systems provide for one method of adjustment, some for the other and some for both. In some cases no special provision has been made for either method of adjustment, but one or the other of these conditions can always be changed. In making cut-out adjustments the following points should be considered. With the cut-out open the magnetism must act across the air gap and consequently this gap affects the speed and voltage of cut-out closing. With the contacts once closed there is little or no air gap between the magnet core and its armature, and therefore the length of the gap has no effect on the time at which the cut-out will reopen. On the other hand, the spring tension is not much changed whether the cut-out be open or closed, and therefore the spring tension will affect the opening and closing about equally.

The cut-out should close just as soon as the dynamo voltage is above that of the battery. With a six-volt battery, the cut-out should close when the dynamo voltage is between 7 and 7½. With batteries of more cells and higher voltage, the dynamo voltage of closing should be in proportion. The cut-out should open when the discharge current flowing through the series coil and from the battery is between zero and two amperes. Improper operation may take place in any of the following ways:

1. Closing at a voltage below that of the battery. This will allow a discharge to take place until the dynamo runs fast enough to raise the voltage. Either the spring tension may be increased or the air gap increased.

2. Closing at a voltage much higher than that of the battery. This will prevent charging at speeds as low as might be used, and the time during which the car is operating below the cut-in speed is lost as far as battery charging is concerned. The remedy is to lessen the air gap or decrease the spring tension.

3. Closing at too high voltage and remaining closed until an excessive discharge takes place. This will lessen the total time during which the battery charges and will increase the time of discharging. Lessen the air gap and increase the spring tension.

4. Closing at too high a voltage and opening before a discharge takes place. Decrease the spring tension.

5. Closing with the dynamo voltage equal to or below that of the battery and remaining closed until an excessive discharge takes place. Allows the battery to discharge. Increase the spring tension.

6. Closing at too low voltage and opening before a discharge takes place. Decrease the spring tension and increase the air gap.

The current carrying contacts of the cut-out must be kept clean and bright and must meet with their whole surfaces in contact. Should the contacts be found dirty or pitted they may be properly fitted by passing a narrow strip of very fine emery cloth between them, then pressing them together and drawing the cloth back and forth. After one contact is cleaned the cloth should be turned over and the surface of the other contact treated in the same way. It should be noted that some contacts are made with a ribbed surface and such forms should not be dressed with emery cloth, as this would destroy the ribs. This method of cleaning may be applied to contacts of metal or of carbon. Carbon contacts can be handled very satisfactorily with fine sandpaper or cloth in place of emery cloth.

The contacts of an electromagnetic cut-out should not be pressed together unless one of the wires from either battery or dynamo can be quickly removed. With the contacts together the flow of battery current around the series coil and through the shunt winding may hold them closed with a resulting discharge from the battery. All cut-outs are not subject to this action, those in which the armature never comes very close to the magnet core generally being free from it. Removing the wire that leads to the dynamo or the one that leads to the battery will stop the flow of current and will allow the contacts to open. Starting the engine will stop the flow from the battery and send it in the other direction. When the engine is allowed to stop, the contacts will open.

Various locations are used for electromagnetic cut-outs, these varying with the design and make of the equipment. In some cases this part of the apparatus will be found inside of the dynamo housing, either in the brush and commutator compartment, in a housing adjacent to the brushes and commutator or underneath the arch of inverted U magnets. The cut-out will oftentimes be carried on the outside of the dynamo case. Either of these methods allow of the minimum length of wiring between dynamo and cut-out and make it necessary to run only two wires away from the dynamo with a two-wire system or one wire with a one-wire system. Other locations for the cut-out are on the dash, under the front seat, under the floor boards, on the cowl board, with the regulating device or with the starting, lighting or ignition switch.

Hand-Operated or Manual Cut-outs.—A number of systems are built in which the electromagnetic cut-out is dispensed with and in its place is used some form of switch that breaks the connection between the dynamo and battery when the engine is not running. This type of cut-out switch is attached to the same handle, button or lever that operates either the starting switch or the ignition switch. When attached to the starting switch the ignition is also operated by the starting switch handle so that it might be said that a manually operated cut-out will always be interconnected with the ignition switch in such a way that the circuit will be closed between dynamo and battery when the ignition is turned on and will be broken when the ignition is stopped.

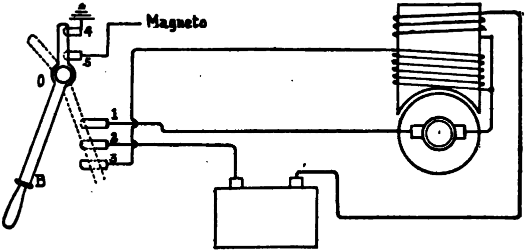


Figure 59.—Manual Cut-Out and Starting Switch (Dyneto-Entz Type).

The action of one form is shown in Figure 59. This type of switch has been extensively used with Dyneto and with Entz equipment, and one similar in principle has been used with Westinghouse and Bijur systems, always in connection with a combined motor-dynamo having one armature and operating as a starting motor at low speeds while changing to a dynamo at higher speeds. The switch is composed of a blade and handle *B*, pivoted at *O*. The position with the engine idle is shown in full lines, while the starting and running position is shown in dotted lines. The form illustrated is designed for use with a high tension magneto and in the off position the line from the magneto armature is grounded through the contacts *4* and *5* which are connected by the short extension of the switch blade on one side of the pivot.

With the switch moved to the running and starting position, the magneto ground is removed and the ignition will become operative. At the same time the current flows from the right hand brush of the dynamo through the series field (reversed for regulating purposes during action as a dynamo) and to the battery. From the left-hand brush current flows to switch contact *1*, through the blade to the contacts *2* and *3*. From contact *2* the charging current passes to the battery and from contact *3* a part of the current passes to the shunt field of the dynamo. Midway between the "Off" position and the "Start" or "Run" position, is a point called "Idle" or "Neutral." With the switch in this position, the ignition ground will be removed and the ignition operative, the contacts *1* and *2* will be connected so that the battery is connected to the starting motor, but contact *3* is disconnected so that the dynamo is prevented from generating because the shunt field circuit is not complete. This position would be used for touring or when the battery has been sufficiently charged.

A variation of this switch is shown in Figure 60 in which the leads to the contacts have been changed. The ignition and starting connections are the same in effect, but with the switch in the position half way between "Off" and "Start" the battery is disconnected and the shunt field is open so that no flow can take place from battery to motor-dynamo at low engine speeds and neither can current be generated by the machine as a dynamo. This has the effect of preventing useless battery discharge when the car is being operated at speeds so low that the dynamo voltage would not be high enough to charge the battery. It also prevents the generation of current while the battery is disconnected because of the opening of the shunt field circuit. Except for this switch, current generated with the battery disconnected would have to flow through the field windings and would be so much greater than these windings are designed to carry that the coils would be burned out. This connection, shown in Figure 60, is the one most used. Similar arrangements are secured by the use of switches of rotary form rather than the knife type

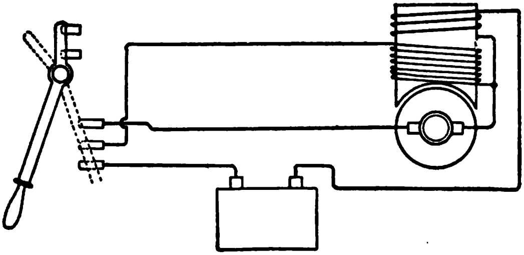


Figure 60.—Manual Cut-Out and Starting Switch (Dyneto-Entz Type).

shown. The principle and the connections made remain the same, regardless of the style of switch used.

A type of cut-out switch that is operated with the ignition switch and that has been used with a great many Delco equipments is shown in Figure 61. When the switch button is pulled out, the contacts *A* and *B* are both closed at the same time. Current for ignition then flows from the battery through the wire to switch terminal *1* and through the wire *X* and the circuit breaker (not shown) to the ignition contacts *A*. From these contacts the flow continues through switch terminal *8* to the ignition coil and then through the ignition breaker to ground, from where it returns to the battery.

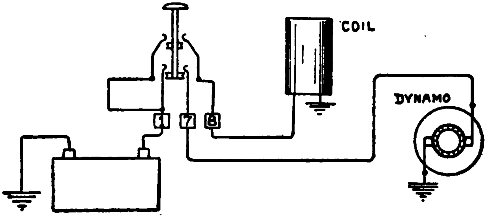


Figure 61.—Manual Cut-Out Switch (Delco).

With the ignition turned on as described, the engine can be started. The dynamo will quickly generate a voltage high enough to cause battery charging, and the flow will take place from the dynamo commutator to switch terminal 7, then through the contacts *B* and through the terminal *1* to the battery. Part of this dynamo current will then pass through the ignition contacts of the switch and will take the place of the battery current supplied while starting the engine. One side of the battery and one side of the dynamo are grounded so that the charging circuit is completed. A discharge of current will take place from the battery through the switch terminals *1* and *7* and through the contacts *B* during the time that the switch is closed and before the engine starts. This reverse flow or discharge will also take place when the engine runs at a speed so low that a charging voltage is not maintained. The proportion of discharge to charge is so very small that its effect on the battery is negligible. When the engine is to be stopped the switch is opened by pressing in on the button and both the ignition and charging circuits are broken. The dynamo is then disconnected from the battery while the engine remains idle.

It is of course impossible to make any adjustments on hand-operated cut-out switches because of the fact that their operation depends on the time at which either the starting switch or the ignition switch is used.

DYNAMO OUTPUT CONTROL

The details of the methods in use for limiting and regulating the battery charge rate in amperes are many. While the applications of the several principles differ more or less from each other in almost every make and every type of equipment, they may be divided into several distinct classes, according to the ways in which they secure the desired result.

Constant Voltage or Control of Current.—All methods of regulation may be classified under two heads. One class causes the dynamo voltage to remain at a constant and unvarying point after the cutout closes, while the other class makes use of principles that allow the voltage of the dynamo to change so that the desired flow in amperes is given to the battery through control of the voltage, but not through keeping it at a constant value. While both methods are in common use, the latter has been used in greater numbers than has the first one.

The rate of flow in amperes from the dynamo to the battery always depends on the difference in voltage between these two units. Should a battery with a pressure of six volts be attached to a dynamo that was generating exactly six volts, there could be no flow, because the two pressures would balance each other. The condition would be similar to that which would exist with a water tank attached to a water pump when the pressure in the tank was six pounds and the pressure from the pump was also six pounds. It is evident that there could be no flow in either case.

It will be remembered from the explanation of volts, amperes and ohms in Chapter I that the amperage flowing through a circuit may be found by dividing the voltage by the resistance of the circuit. The resistance of the wiring and connections between dynamo and battery, plus the resistance of the battery itself, make up the total resistance of the charging circuit, and the voltage acting will always be the difference between that of the dynamo and of the battery. For purposes of explanation, it may be assumed that the resistance through the charging circuit will remain unchanged at all times, and in the following explanation on this subject, this condition has been taken for granted.

It will then be evident that any increase of dynamo voltage above that of the battery will result in an increased flow and the change of flow will be in proportion to the change in difference of voltage between dynamo and battery. Two things will always act to increase the dynamo voltage with a straight shunt wound machine, these being increase of armature speed and increase of current flowing around the field coils. With a shunt wound dynamo these will increase together for the reason that increased voltage at the brushes caused by increased speed will result in an increased flow through the field windings because of this higher voltage. The total result will be a still further increase in generated voltage, also a corresponding increase of amperage through the circuit.

The dynamo armature is generally driven positively from the engine at all speeds so that its speed increases directly in proportion to increase of car and engine speed. The dynamo voltage would therefore naturally rise continuously from the lowest to the highest speeds. In some cases the speed is limited by a governor that releases the driving connection when the desired number of revolutions per minute has been reached and the dynamo cannot generate a voltage in excess of that caused by this maximum speed. With the generally used type of dynamo operating at a variable speed the method of output control will act to decrease the field strength with increase of speed so that the weakened field counteracts the more rapid rotation of the armature to a greater or less extent and the dynamo voltage is held within certain desired limits. Another method makes use of the change in direction of the lines of force through the armature. Depending on the method used, any of the following effects may be secured:

1. An increase of voltage throughout the whole range of dynamo speed, the voltage, however, increasing less rapidly at high speeds than at low.

2. A gradual increase of voltage until a maximum is reached at some critical speed, followed by a falling off in voltage as the speed becomes still greater.

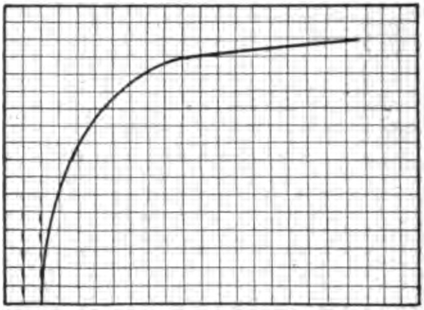


Figure 62.—Output of Dynamo Having Gradual and Continuous Increase (Reversed Series).

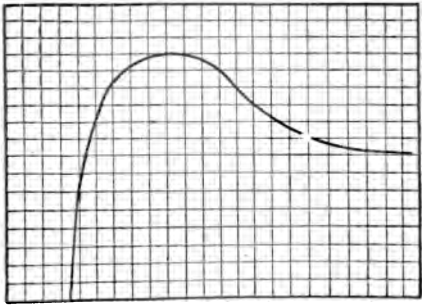


Figure 63.—Output of Dynamo Having Quick Rise to Maximum, Followed by Decrease (Third-Brush).

3. A comparatively sudden rise in voltage through the low speed ranges until a critical point is reached, after which the voltage is maintained at a point just

sufficient to cause a constant amperage to flow from dynamo to battery.

The characteristics of the three types are shown in Figures 62 to 64. The rate of speed corresponds to the series of vertical lines, and increases from left to right. The voltage and consequent amperage flowing are indicated by succession of horizontal lines, and the increase is from bottom to top. Figure 62 represents the condition numbered "1" in the foregoing explanation. Figure 63 represents the condition outlined in number "2," while Figure 64 shows the result obtained in number "3." These types include the methods that are classed as amperage control, or limited output control, but do not represent the second general classification known as constant voltage or "constant potential."

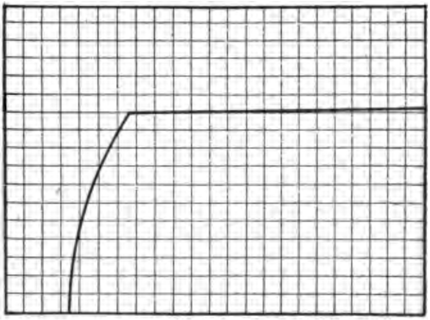


Figure 64.—Output of Dynamo Having Constant Amperage Regulation.

Constant Voltage.—It was explained in Chapter III that the voltage of the battery increased as the charge progressed and that the voltage of a fully charged battery is higher than the voltage of a battery that is discharged or partially discharged. If a dynamo is operated in such a way that the voltage generated will remain constant at one value over practically the whole range of armature speed it will be seen that the difference in voltage between the dynamo and battery will depend not only on the dynamo but also on the voltage of the battery at any particular time. With a nearly discharged battery of low voltage, the difference between dynamo and battery will be comparatively great, while with a battery that is nearly charged and of correspondingly high voltage, the difference will not be so great. For this reason the flow from the dynamo to a discharged or partly charged battery will be caused by a comparatively large difference of voltage, and this flow will be relatively great in amperage. The flow from the constant voltage dynamo to a battery that is nearly or fully charged and of correspondingly high voltage will be caused by a smaller difference in pressure, and the amperage will therefore be relatively small. This

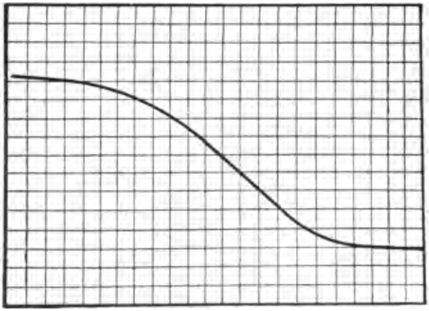


Figure 65.—Output of Dynamo Having Constant Voltage Regulation.

action gives what is known as a "tapering charge," that is, a charge whose amperage becomes less and less as the battery becomes charged and as the battery voltage increases. The characteristics of such regulation are shown in Figure 65, in which the percentage of battery charge from zero to full charge is shown from left to right while the amperage or voltage difference is shown by the horizontal lines and decreases from top to bottom. In this connection it should be borne in mind that the specific gravity of the battery electrolyte increases with increase of battery voltage, and it may therefore be stated that the rate of charge in amperes will be greater at low specific gravities than at high.

Output or Voltage Regulation.—Four principal methods or devices are in use for securing control of the dynamo voltage and output. They may be classified as follows:

I. Inherent characteristics of the dynamo design that do not require the use of any additional moving parts but that secure the desired results through the peculiarities of electric currents, conductors and magnetism. This class includes compound and reversed-series field windings, also a variation somewhat similar to the reversed series and known as a "bucking coil." A type of dynamo having one or more brushes in addition to those for the charging lines is also included in this class, this type being known as the "third brush" machine. In this case the added brushes carry the field current for the shunt winding.

II. Electromagnets that act to increase the resistance of the shunt field circuit, or to open the shunt field under certain conditions, or to make changes in the field circuits.

III. Centrifugally operated governors that act to prevent an armature speed above a predetermined limit or that insert a resistance in the field circuit or charging circuits.

IV. Ampere-hour meters that change the field circuit resistance according to the number of ampere hours that pass into or out of the battery.

The four classes just mentioned are found in a total of sixteen different applications, each of the sixteen being a distinct type of regulation and used by one or more makers of electrical equipment. Each application will be described, and when used by a limited number of makers, their names will be given in connection with the description. The applications under each division are as follows:

I. Inherent Characteristics.
  (1) Reversed-series field winding.
  (2) Third brush for shunt field current.
  (3) Compound field windings.
  (4) Bucking coil (iron wire control).

II. (5) Magnetic vibrator inserting field resistance.
  (6) Magnetic vibrator energizing bucking coil.
  (7) Magnetic vibrator for field resistance, with load control.
  (8) Magnetic controlled carbon field resistance.
  (9) Magnet acting to open field circuit.
  (10) Solenoid operating rheostat field resistance.

(11) Magnet and mercury well control of field resistance.
(12) Changing combinations of fields and windings.

III. (13) Speed control governor with compound field winding.
(14) Speed control governor with permanent field magnets.
(15) Governor inserting field resistance.

IV. (16) Ampere-hour meter control of field circuit.

The numbers that appear at the beginning of each of the following descriptions refer to the numbers given in the foregoing list of applications.

(1) The principle upon which the reversed-series field winding system operates has been described in Chapter II, and a lengthy description is therefore unnecessary at this time. The application of this method of regulation in one type of Auto-Lite dynamo is shown in Figure 66. This machine carries two windings on each of the field magnet poles, one winding being the usual shunt and the other one being a series coil through which the current, passing from dynamo to battery, flows in a direction the reverse of that taken by the current passing through the shunt coils. From the lower brush, which is positive, current passes to both coils on the lower pole piece, part passing through the shunt field in such a direction that this pole end is made positive. This current is then carried to the upper shunt field winding and passes around this upper pole piece in such a direction that

its end is also made positive. The consequent poles thus formed at either side of the armature are therefore negative.

The portion of the current from the positive brush that is not required for the shunt field, passes around the lower pole piece in a direction that tends to oppose the shunt winding and to make this pole end of less strength. After passing around the magnet, the current is led to the lower terminal and then to the battery. The current returning from the battery to the

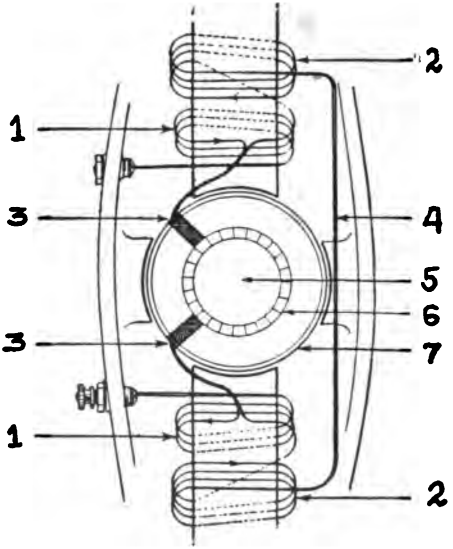


Figure 66.—Dynamo Having Reversed Series Regulation (Auto-Lite).

1—Series Field Windings.
2—Shunt Field Windings.
3—Brushes.
4—Connection for Shunt Windings.
5—Dynamo Shaft.
6—Commutator.
7—Armature.

upper dynamo terminal, comes into the upper series winding and passes around the magnet in a direction that tends to weaken this upper pole, thus opposing the shunt winding. Having traveled around the windings, the current joins with that from the upper shunt coil and is led to the negative brush. While this exact method of winding is not always followed, the principle is the same in all applications of this method, that is, to cause the charging current passing around the series windings to oppose the effect of the shunt winding.

(2) Third brush regulation depends on two electrical facts. One is the fact that the voltage between a brush of a two-pole dynamo and point on the commutator away from this brush depends on the distance of the point from the brush and becomes greater as the distance increases. The greatest voltage difference will therefore be secured between opposite points on the commutator. If one end of the shunt field winding be connected to one brush and the other end of the winding lead to a brush that is not directly opposite the first one, the difference in voltage acting to send current through the shunt field will not be as great as if the field were connected between brushes directly opposite. If, then, the field current is to be increased, the second brush may be moved farther away from the first one and this movement will allow a greater difference in voltage to act on the field and a correspondingly greater flow in amperage and field strength will result. The field strength may be decreased by bringing the brushes to which the winding is attached nearer together. The brush that carries one end of the winding is generally made movable, and the output of the dynamo may be increased or de-

creased by moving the brush away from or toward the stationary brush. While such brushes may be made movable for purposes of adjustment, they are locked in one position while the dynamo is in operation, the control of voltage being secured, not by continually moving the brush, but as described in the following paragraphs.

The connections for regulation in such a system are shown in Figure 67, the type shown being used with several models of Remy dynamos. The principle and action will be the same, regardless of the make of equipment or its model, so long as the third brush system is used. Current for charging is taken from the main brushes marked *A* and *B*, these being indirectly connected to the battery. The shunt field current passes through the brush *R* and to the field coil, then through the field fuse which is used to protect the field winding against excessive current flow, and from the fuse the field current returns to the brush *B*. The difference in voltage between brushes *R* and *B* is the voltage that acts to send current through the field coil. Were it possible to change the regulating brush position, moving it down (toward brush *B*) would de-

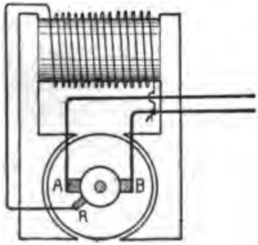


Figure 67.—Dynamo with Third Brush Regulation.

crease the output of the dynamo, while moving it up (farther from *B*) would increase the output.

At low speeds the flow of magnetism or magnetic lines of force between the poles of the field magnet is shown in Figure 68. It will be seen that the flow is practically straight across, and because of this direction of the lines of force through the armature, the coils which are at any instant in connection with the brushes, cut through the greatest possible number of lines of force, and therefore the greatest difference in voltage will be between the commutator points being touched by the main brushes *A* and *B*. A less difference in voltage will be maintained between the points touched by the brushes *R* and *B* because of the smaller number of lines of force being cut by the corresponding armature coils.

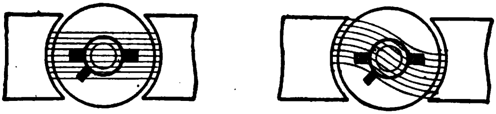


Figure 68.—Distortion of Field Magnetism for Third-Brush Regulation.

With increase of armature speed, the lines of force do not continue to pass straight across, but are carried part way around in the direction of rotation by the core of the armature. With the magnetism flowing in this distorted path, the armature coils that are at any one time attached to the regulating brush through the commutator, are not cutting as many lines of force as at lower speeds, and the voltage difference between the brush *R* and the brush *B* is less than with the lines of force passing straight across. This reduction of voltage causes the amperage passing through the shunt field to decrease, and even with the rise in armature speed, the output does not increase proportionately because of the weakened field. With further increase of armature speed, the path of the lines of force is still further distorted and the field current drops to such an amperage that the total output of the dynamo becomes less and less through the highest speeds of rotation. The relation of dynamo output to armature speed is shown by the curve in Figure 63.

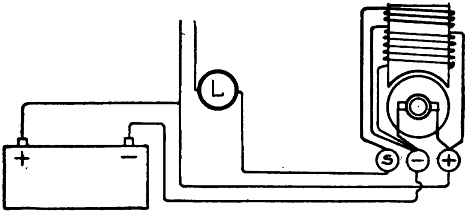


Figure 69.—Compound Wound Dynamo with Lamp Circuit Through Series Field (Gray & Davis).

(3) The compound-wound dynamo is generally used in combination with some of the other methods of regulation. This machine makes use of a straight shunt winding on the field magnets, and in addition to this shunt winding, has a series coil through which current flows in the same direction as through the shunt and increases the field strength. Such an arrangement is shown in Figure 69, this connection being that used with some older types of Gray & Davis dynamos that were equipped with a centrifugal governor to limit the dynamo speed.

In this case it will be seen that current for the lamps is carried through the series field winding, and when the lamps are lighted, the strength of the series winding will be added to that of the shunt with a consequent increase in dynamo output to care for the added load placed upon the system by the lighting of the lamps. With no lamps lighted, current from the dynamo brushes flows to the terminals marked + and – and from these terminals to the positive and negative terminals of the battery. Should the lamps be turned on, the current taken by the bulbs will not pass to the battery, but from the + dynamo terminal through the wire *A* to the lamps, then through the lighting switch *L* and wire *B* to the dynamo terminal *S*. From this terminal the lamp current passes around the series coil, then to the dynamo terminal marked – and back to the negative brush. Should enough lamps be turned on to take more current than that being supplied by the dynamo, the deficiency will be furnished by the battery. This extra current will come from the positive battery terminal to the lamps, then through the bulbs and lamp switch to dynamo terminal *S*, through the series field so that it is still further strengthened and back to the battery from the dynamo terminal marked –.

(4) The system of regulation known as "iron wire" control was introduced on the dynamos made by the Rushmore Dynamo Works and is also used on some of the products of the Bosch Magneto Company of which the Rushmore Dynamo Works is a part. The dynamo field magnets carry a shunt winding, and in addition to the shunt, a second winding of fewer turns through which current is forced to flow in a direction opposite to that in the shunt coils by a peculiar property of iron wire. A field coil, so wound that current passes

through it in a direction that opposes the shunt field action, is called a "bucking coil." In this case the coil is not a series coil and does not carry the entire dynamo output, therefore the system cannot be classed as a reversed-series type.

Iron wire will carry a volume of current in proportion to the gauge size, just as any other metal carries current. Up to a certain amperage the wire will remain comparatively cool, but as soon as this amperage is exceeded, the wire will become very hot and with increase of temperature, its resistance increases to such a point that but very little flow of current can take place through the wire.

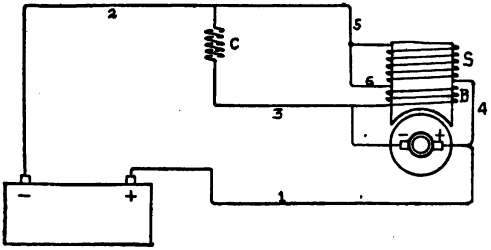


Figure 70.—Principle of Rushmore Iron Wire Regulation.

The use of iron wire in the Rushmore system is shown in Figure 70. Starting at the right-hand brush, the charging current flows through wire *1* to the battery, through the battery and by wire *2* to one end of the ballast coil *C*. This ballast coil is made from a certain gauge size of iron wire and always carries ten feet of the size used. Passing through the ballast coil and wire *3*, the current returns to the negative dynamo brush. Again starting at the right-hand brush, the field current passes through wire *4* to the shunt field winding *S*, through the coil and by way of the wire *5* to the ballast coil, and through the iron wire to wire *3* and the negative brush. It will thus be seen that the bucking coil field winding *B* carries practically no current under ordinary conditions.

When the amperage reaches a certain value, the iron wire becomes very hot and further increase of current flow through it is prevented. This prevents increase of flow through wires *5* and *3*, and the field current that formerly passed through wire *5* must now take the path through wire *6*, through the bucking coil and to the negative brush. This flow of current through the bucking coil decreases the field strength and dynamo output. With decrease of output, the iron wire cools and the current again takes its normal path and leaves the bucking coil weak as before. By selecting a gauge size of iron wire that will keep just below the critical temperature while carrying the desired charging current, the output of the dynamo is prevented from exceeding this amperage.

(5) A great many systems make use of a regulating device comprising an electromagnet whose strength increases with increase of dynamo voltage and which causes a high resistance to be temporarily inserted in the shunt field circuit when the dynamo speed becomes high enough to cause excessive voltage and therefore excessive amperage. The principle of such a mechanism is shown in Figure 71. The three dynamo terminals are marked *F*, *A* and *D*; *F* being attached to one end of the shunt field winding, *A* to one of the dynamo brushes, and *D* to the other brush and the remaining end of the field winding. The regulator consists of the magnet *M* around which current from

dynamo terminal *A* flows through the wire *1* on its way to the battery. It will be seen that this magnet will become stronger as the amperage passing from the dynamo to battery increases. The armature of this magnet is held away from the core by the spring *B,* and with the armature in this position, the contacts *C* are closed.

Current for the shunt field leaves the dynamo at terminal *A,* passing through the wire *1* to the contacts.

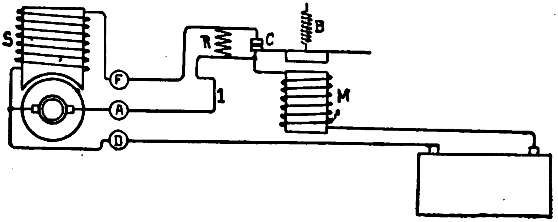


Figure 71.—Electromagnetic Regulator for Constant Amperage.

This current does not flow through the coil *R* because this coil is made from wire with a very high resistance, but the current takes the path of low resistance through the contacts. From the upper contact the field current passes to dynamo terminal *F,* through the shunt field winding and to the left-hand brush. As long as the amperage flowing to the battery around the magnet *M* is not great enough to cause the magnet to overcome the tension of the spring *B,* the above conditions hold true. The spring tension is set at such a point that when the desired maximum amperage of charging is reached, the magnet attracts its armature and the contacts *C* open. The field current can no longer pass through the contacts, but must take the path through the resistance coil *R.* This resistance allows but a small current to pass through the field, with a consequent reduction in field strength and dynamo output. The decreased output results in a lessened flow around the magnet *M*, and the contacts are again closed by the tension of the spring *B*. In practice this opening and closing of the contacts is so rapid as to be almost imperceptible to the eye, and the field current is maintained at such a strength that the dynamo output cannot exceed the maximum for which the spring tension is set, regardless of dynamo speed. Increasing the spring tension or increasing the air gap between magnet core and armature will raise the amperage that the dynamo will give, while decreasing the spring tension or lessening the air gap will result in a lower amperage for charging. This principle has been used in controllers made by Allis-Chalmers, Delco, Disco, Gray & Davis, North East, Remy, Simms-Huff, and Ward Leonard.

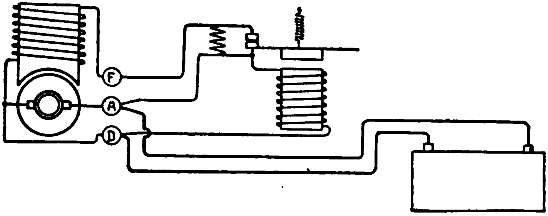


Figure 72.—Electromagnetic Regulator for Constant Voltage.

The variation of this method, shown in Figure 72, illustrates the connections when it is desired to maintain a constant voltage at the dynamo rather than a limited amperage, regardless of dynamo speed. The sole difference is that the magnet *M* now has its coil connected to the dynamo brushes through the terminals *A* and *D*. Whatever voltage exists between the dynamo brushes will therefore act on the magnet winding. The strength of the magnet will increase with dynamo voltage, and will decrease with drop of dynamo voltage. The tension of the spring is set at a point such that the armature will remain away from the magnet core and the contacts will remain closed until the dynamo voltage reaches the value that is desired. At this voltage the magnet overcomes the spring tension, the field current is forced to pass through the resistance coil, and the lessened flow through the fields causes an immediate drop in voltage. This drop in voltage weakens the magnet so that the contacts are again closed by the spring, and the operation is repeated at an extremely rapid rate. The result is that the voltage of the dynamo will not rise above the point that the spring is set for, regardless of the dynamo speed. The magnet winding in this case is made from a great many turns of very fine wire, so that but little current will flow through it. The battery is connected between dynamo terminals *A* and *D* so that current for charging does not pass through the regulator. Increasing the spring tension or increasing the air gap between magnet and armature will raise the operating voltage of the dynamo, while decreasing the spring tension or the air gap will lower the dynamo voltage.

Systems using the vibrating form of regulator practically always make use of an electromagnetic cut-out with it. The two units are combined in one housing and called a controller. The controller may use two magnets, one for the regulator and one for the cut-out, or may use but one magnet with two windings for both functions. Such a combination is illustrated in

Figure 73. The single magnet is so arranged that it will attract the right-hand armature for cut-out action and the left-hand armature for regulator action. This magnet carries a fine wire coil *S* which is the shunt coil for the cut-out action, and also a coil of heavy wire *C* which acts as the series cut-out coil and as the main coil for the regulator in a way similar to that of the type shown in Figure 71. The field resistance is shown at *R* and the four terminals used with this type of controller at *F*, *A*, *DB* and *B* on the controller case.

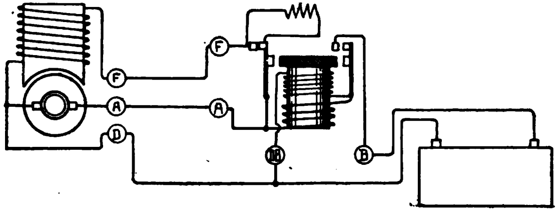


Figure 73.—Controller Connections with Magnetic Cut-Out and Constant Amperage Regulation.

The action is as follows: When the dynamo is idle, the cut-out contacts *Y* are open and the regulator contacts *X* are closed. When the dynamo generates a difference of voltage, current flows from dynamo terminal *A* to controller terminal *A*, through the coil *C* on the magnet, then through coil *S* to controller terminal *DB* and to dynamo terminal *D*. The field circuit is completed from dynamo terminal *A* to controller terminal *A*, through the closed contacts *X* and from controller terminal *F* to the dynamo field terminal, through the shunt field and to the left-hand brush. The flow of current around the magnet causes the cut-out contacts *Y* to close when the dynamo voltage is high enough to charge the battery, and the flow from dynamo to battery passes through coil *C* to the contacts *Y* which are now closed, then to controller terminal *B* and to the battery. When the amperage flowing through the coil *C* reaches the desired maximum, the left-hand armature is attracted to the magnet and the contacts *X* are drawn apart. The field current then passes through the resistance *R* and the regulating action is the same as that already described.

(6) A vibrating system that is seldom met with makes use of a magnet similar to those just described. When the contacts are drawn apart by excessive amperage through the charging circuit, the field current is forced to pass around a series of bucking coils on the field magnet poles. The bucking coils thus take the place of the resistance used with the type described under (5). Jesco systems have made use of a vibrating regulator that utilized a resistance coil and also caused part of the field current to pass through bucking field coils.

(7) The diagram of the circuits of the Gray & Davis controller shown in Figure 74 illustrates the use of a magnetic vibrator that is affected by the lamp load in such a way that the output of the dynamo is automatically increased whenever lamps are lighted with the engine running. It will be seen that current from the positive brush flows through a ground connection for battery charging and that the current used for exciting the fields flows from the positive brush through the upper and lower fields and then to the controller terminals between which is fastened the resistance coil. The regulator contacts are normally closed so that the field current passes through

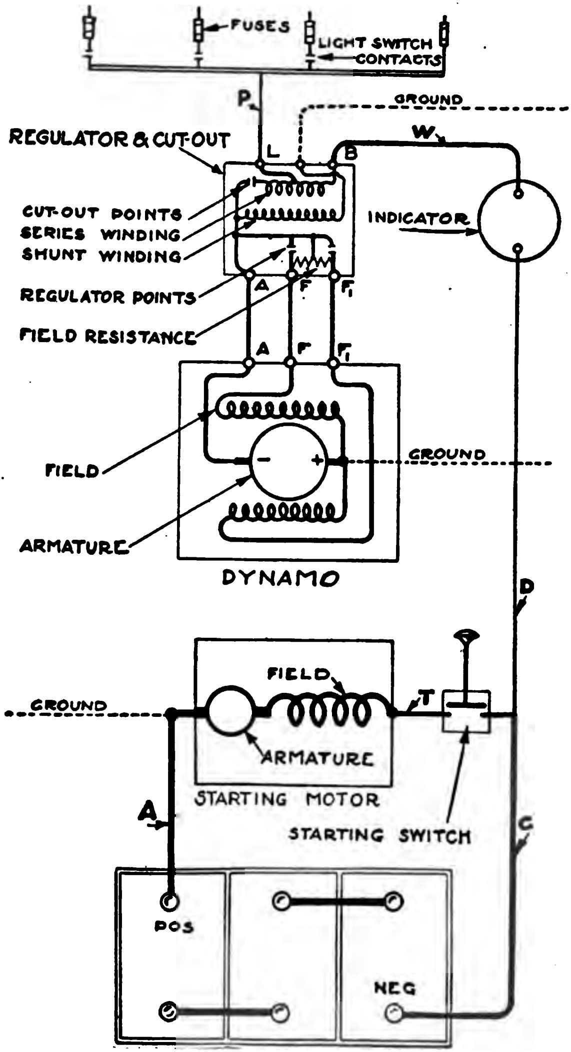


Figure 74.—Controller Connections with Lamp Load Through Windings (Gray & Davis).

them and by way of the wire back to the negative brush.

Current for the shunt winding on the controller magnet enters the controller through the grounded terminal, passes through the magnet winding and then through the controller terminal *A* to the negative brush. The positive brush is grounded so that the magnet circuit is completed, and the cut-out contacts will close when the dynamo voltage is high enough.

The path of the changing current is from the positive brush to ground and from ground to the battery. After passing through the battery, this current flows to the controller terminal *B*, through the series winding of the magnet and by way of the closed cut-out contacts and the terminal *A* to the negative brush. The series coil also acts as the regulator winding and when the amperage has reached the point for which the adjustment is set, the regulator contacts are drawn apart. The field current then flows through the resistance coil and this resistance reduces the dynamo output. The amperage flowing through the series magnet winding determines the point at which the regulator will act and accordingly limits the dynamo output.

It will be noted that the lamp circuits are attached to the controller terminal *L*, and current for the lamps must pass through this terminal. With lamps turned on, the entire flow of dynamo current would not return through the cut-out contacts to the negative dynamo brush, but a part of it would leave the series magnet winding at the point from which a connection leads to controller terminal *L*. The part of the current that is thus used for lighting does not pass all the way through the series winding, and the strength of this winding is therefore reduced in proportion to the current flowing to the lamps. With a decreased strength of this magnet, the regulator contacts will not open so soon and the dynamo output will reach a higher value before the regulator acts. This additional output compensates in a measure for the current required for lighting. Devices of similar action are used with other makes of equipment, the application illustrated serving, however, to demonstrate the principle involved in all of them.

(8) The resistance of carbon is sufficiently great to make it well suited for use as field resistance. Two forms of carbon have been used for this purpose, one being a number of carbon discs, such as found in some models of U. S. L. and Aplco equipment, and the other being finely divided, or powdered, carbon mixed with flake mica, as used with the Bosch voltage regulator.

Carbon discs are used by carrying them in the form of a pile laid one against the other. They are normally held tightly together by the action of a spring, and in this condition their resistance is very low. The armature of the regulator electromagnet is attached to the spring bar in such a way that the power of the magnet acts to release the spring tension. This will happen when the amperage passing through the magnet becomes excessive. The carbon discs are thereby released, and the poor contact between adjacent discs interposes a high resistance in the field circuit, which is completed through the carbon, and the dynamo output is reduced.

When powdered carbon is used, it is carried in a cup and is compressed by a plunger. Attached to the plunger is a rod that passes through a magnet winding, and with increase of amperage through this winding, and consequent increase of magnet strength, the pressure exerted by the plunger is released. The springiness of the flake mica then forces the particles of carbon apart, and the resistance of the mass is increased over what it would be in the compressed state. The field circuit is completed through the carbon mass and the plunger is held down by a spring. When the magnetism overcomes the tension at which the spring is set the field current is reduced and further rise of dynamo voltage is prevented.

All of the carbon resistance systems are adjusted by changing the spring tension. Increase of spring tension holds the carbon together until a higher amperage or dynamo voltage is reached and decrease of the tension lowers the output. The U. S. L. controller, Figure 75, is adjusted by turning a small screw to the end of which is attached the coil spring that holds the carbon pile pressure arm. The Aplco controller has an adjusting screw projecting from the bottom of the case, while the Bosch controller makes use of an oval shaped spring whose tension is changed by turning in or out on a tapered plug that passes over one side of the spring.

(9) The regulating device for one of the Aplco systems makes use of an electromagnet whose winding is connected across the terminals of the battery so that the magnet increases in strength as the voltage of the battery increases. The field circuit is completed through the contacts controlled by this magnet, and when the battery voltage reaches the point that corresponds to the tension of the adjusting spring,

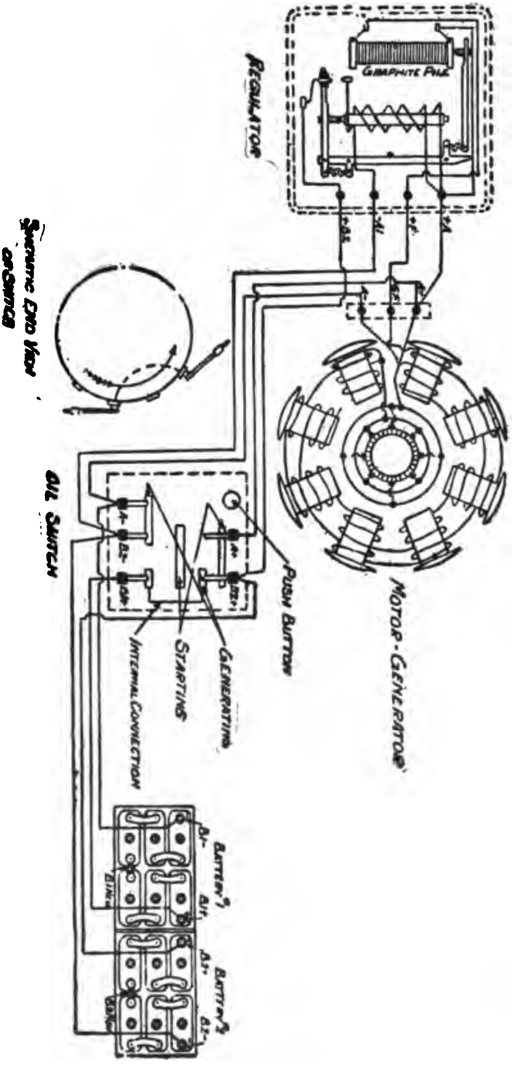


Figure 75.—Controller with Carbon Disc Field Resistance (U. S. L.

the contacts open and, except for that passing through a resistance coil, prevent further flow of current through the shunt field of the motor-dynamo. This stoppage of the field current prevents further charge of the battery until its voltage falls.

(10) The controller used with Adlake equipment carries a rheostat which is controlled by the action of a plunger passing through the center of a magnet winding. See Figure 76. The rheostat consists of an arm pivoted at one end and carrying a carbon brush at the other end. This carbon brush travels over a series of contact segments as the arm moves up and down. One end of the field circuit is attached to the sliding arm and the other end to one end of the series of segments. Between each pair of adjacent segments is placed a small coil of resistance wire, and with the end of the arm resting on the contact segment farthest from the one carrying the end of the field circuit, it will be necessary for the field current to pass through each of the resistance coils in flowing from the arm to the end of the field circuit that attaches to the segments. With the arm resting on the segment to which is attached the end of the field circuit, the field current does not have to pass through any of the resistance coils. This latter position is the one assumed by the arm with the dynamo idle or running at very low speeds.

The entire dynamo output passes through a magnet winding and inside of this magnet winding is placed an iron plunger. This plunger is supported by a small cable that passes around a pulley attached to the sliding arm pivot, and as the plunger is drawn into the coil by increase of magnetism and amperage,

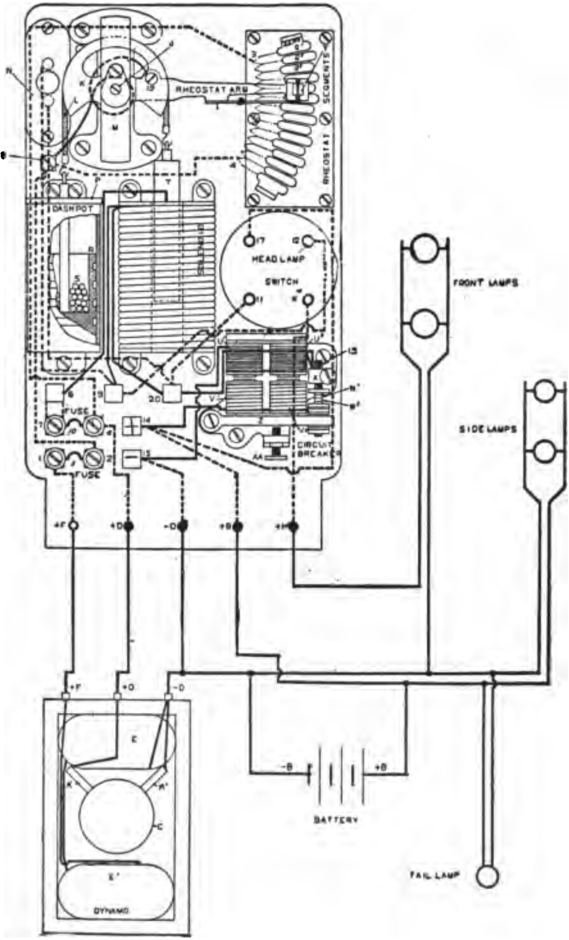


Figure 76.—Controller with Solenoid and Field Rheostat (Adlake).

the arm is caused to travel over the segments and thus place additional resistance in the field circuit. The dynamo output is altered by changing the weight carried by the plunger. Increasing this weight will raise the dynamo output, while decreasing it will lower the output.

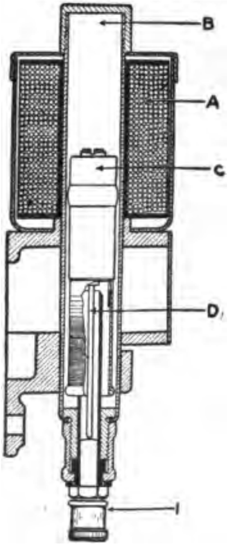


Figure 77.—Controller Using Mercury-Well Principle (Delco).

A—Magnet Winding.
B—Plunger Cylinder.
C—Plunger Core.
D—Plunger Rod in Mercury Well.
1—Field Circuit Connection.

(11) A number of Delco systems have been fitted with a regulator known as the "mercury well" type. See Figure 77. This regulator includes a tube made from insulating material and carrying a coil of resistance wire wound around it. The lower end of this coil of wire dips into a well, or pocket, in which

is carried a quantity of mercury. The field circuit is completed through the resistance wire and the mercury, one end of the field circuit attaching to the wire and the other end to the mercury well. With the dynamo idle or running at low speeds, the plunger tube drops down into the mercury so that the field current does not have to flow through a great length of the coil, but passes directly into the mercury and through the well with its comparatively small resistance.

Around the upper end of the tube is placed a magnet winding, and the upper end of the tube forms an iron plunger. The magnet winding is attached between the dynamo brushes, and with increase of dynamo voltage, the strength of the magnet winding is increased. This magnetism will finally lift the resistance tube so that a greater length of the wire is held up out of the mercury. The field current is reduced by flowing through this additional resistance, and the dynamo voltage is prevented from rising above a predetermined point. The voltage is adjusted by changing the resistance in the magnet circuit either by means of a small lever on the regulator or by placing a connecting link of high or low resistance between regulator and cut-out, a higher resistance allowing an increased voltage.

(12) A method of regulation rarely used has been employed with some of the older models of Deaco equipment. These dynamos carry permanent field magnets, and in connection with these magnets, have a set of shunt field coils. An electromagnet is carried underneath the arch of the permanent magnets, and by opening and closing contacts with increase of

dynamo output flowing around the magnet winding, the following action takes place:

At low dynamo speeds the shunt field windings assist the permanent magnets and a relatively high output is maintained. With increase of speed and voltage, the shunt field circuit is opened and the permanent magnets act alone, the loss of the field winding strength serving to counteract the increased speed. With a still further increase of speed, the circuit is completed through the shunt field windings, but with the current flowing in such a direction that the windings oppose the permanent magnets. At this time the field current flows through a length of resistance wire. At the highest dynamo speed the resistance is removed from the shunt field circuit and the full field strength opposes the magnetism of the permanent magnets. The steadily increasing dynamo speed is opposed more and more by the decrease in strength of the fields, and the output of the dynamo is held at practically a constant value.

(13) The voltage acting on the field circuits of a shunt wound dynamo is primarily determined by the speed of armature rotation. If this speed were to be kept constant, and at the same time the resistance through the outside circuits were to remain practically constant, the dynamo voltage would remain at the same point. This effect is secured in some systems, notably in a large number of Gray & Davis dynamos made previous to 1915. Dynamos of this make and with this type of regulation have also a compound field winding through the series coils of which the lamp current passes as described under (3) in this chapter.

The armature shaft is not connected directly with the engine, but is fastened instead to a framework that carries two friction shoes. See Figure 78. These shoes are held in contact with the inner surface of a cylindrical drum, or in some cases, the shoes are replaced with a flat disc and this disc is held in contact with a similar disc by the tension of adjustable springs. The drum, or the second disc, is attached to the dynamo drive shaft and as long as the two parts, shoes and drum or discs, are held together, the armature shaft will be driven at the same speed as the drive shaft. Therefore, as long as the two driving parts are together the dynamo speed will rise and fall in direct ratio to the engine speed. Two governor weights are fastened to the armature shaft and revolve with it. The arms carrying these weights are attached to the shoes or to the movable disc in such a way that when the weights are caused to fly apart by centrifugal force the shoes are drawn away from the drum or the discs are drawn apart. The driving parts

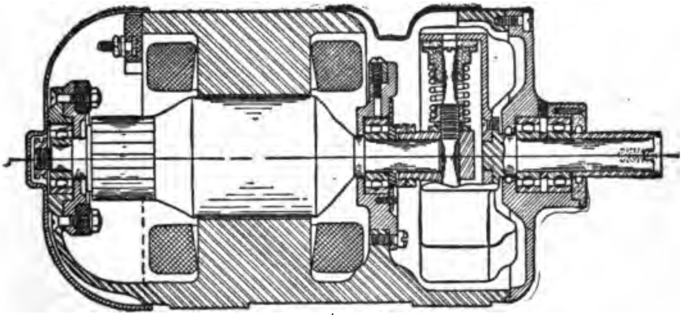


Fig. 78.—Friction Clutch for Limiting Dynamo Speed (Gray & Davis).

are normally held together by coiled springs, and when the pull of the rapidly revolving weights is sufficient to overcome the tension of these springs, the armature shaft is released from the driving shaft and the speed of the armature will not be increased above this point.

The dynamo voltage and output is changed by changing the tension on the governor spring or springs. Increasing the spring tension will cause the armature shaft to remain connected to the driving shaft until a higher speed is reached and the output will show a corresponding increase. Decreasing the spring tension will prevent the armature from revolving at such a high speed and the output will be reduced.

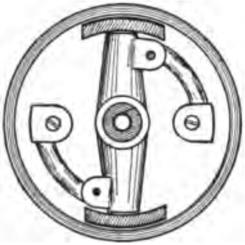


Figure 79.—Friction Clutch for Limiting Dynamo Speed (Auto-Lite).

(14) A form of governor operating on the same principle as the one just described has been used with older models of Auto-Lite dynamos. See Figure 79. The governor consists of a drum fastened to the driving shaft and of two shoes, each one attached to a weight and held in contact with the drum by the tension of a spring. In this case the spring tension is

not changed, but dynamo output is altered by moving the weights on their supporting arms. The weights are held in place by screws, and as the weights are moved farther from the pivotal point of their respective arms, they produce a releasing effect at a lower speed and consequently reduce the dynamo output. Moving the weights in on the arms increases the dynamo voltage and output. Dynamos that are fitted with this form of regulation and of Auto-Lite make are fitted with permanent field magnets.

(15) One other application of the centrifugal governor has been used, this being the system applied to certain models of Vesta dynamos. These machines use permanent field magnets, and the regulator is carried at one end of the dynamo housing. The governor weights are attached to a sliding ring, and as this ring moves along its shaft under the action of the flying weights, it compresses an adjusting spring. Attached to the sliding ring is an arm whose outer end travels over a rheostat. This rheostat consists of a number of segments, the end one being disconnected from all wiring and each pair of the remaining segments carrying a coil of resistance wire between them. With the dynamo idle, or running at very low speeds, the end of the arm rests on the segment that has no connection. The charging circuit is attached to this arm, and when the end of the arm is on the disconnected segment, the dynamo is disconnected from the battery. This part of the governor acts as a cut-out.

As the arm travels over the segments with increase of armature speed and centrifugal force from the weights, a continually increasing number of resistance coils is inserted in the charging circuit and an excessive battery charge is thereby prevented. The time of cutting in and out as well as the dynamo output is adjusted by changing the tension of the governor springs. There are two springs, one acting to regulate the time of cut-out action and the other being for output regulation.

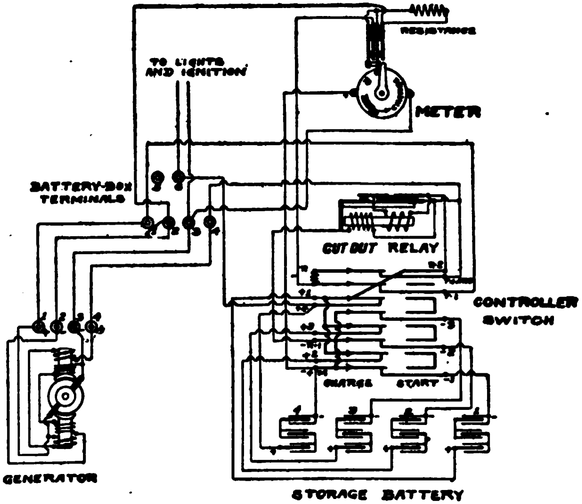


Figure 80.—Connections for Ampere-Hour Meter Regulator (Delco).

(16) The first Delco systems to be used during 1912 and 1913 were equipped with an ampere-hour meter that measured and indicated the number of ampere-hours that passed into or out of the battery. This meter, Figure 80, is attached in such a way that all of the current entering the battery from the dynamo causes an indicating hand to travel in a counterclockwise direction, while all current leaving the battery for lighting, starting and other purposes causes the hand to travel around its dial in a clockwise direc-

tion. Carried in the meter case is a set of contact points through which the field current must pass, and movement of the meter past a certain position causes first one pair of contacts to open, and with further travel in the same direction during battery discharge, causes the other set of contacts to separate. With the first set of contacts open, the field current must pass through a length of resistance wire, thus reducing the field strength and charging current. When the second set of contacts open, the field circuit is opened altogether and further charge is stopped because there is practically no field strength.

As the battery continues to charge without a proportionate discharge the meter hand comes around to a point at which the first set of contacts will open. Should the use of the car go on without calling for any considerable discharge from the battery, the meter hand will finally travel to a position that will open the second set of contacts and the charge will be stopped. If now the battery current be used, the meter hand will revolve in the opposite direction and the second set of contacts will close. The dynamo will then start to generate current at a low rate because of the completion of the field circuit through the resistance wire. With further net discharge of the battery the first set of contacts will close and the dynamo charge will reach its full value. With this system in operation it is necessary to move the hand in the direction of discharge at intervals of about two weeks because of the fact that a storage battery must have a greater number of ampere-hours charge than discharge. The meter hand is held in place by a toothed joint, and by lifting it up, it may be reset to give the necessary additional charge.

It should be noted in connection with the adjustment of regulating devices and the consequent changing of dynamo outputs that this is necessary only under exceptional conditions. The adjustment made by the manufacturers of the car or of the electrical equipment is correct for that car under average conditions, and it should never be altered until the person doing the work is sure of reasons sufficient to warrant the change. It will usually be found that low dynamo outputs are due to lack of proper care in cleaning brushes and commutators, in keeping wire connections clean and tight and in keeping the battery clean and filled with pure water.

It is, however, possible that unusual conditions of service may call for a change in dynamo output. For instance, a car that is driven mostly at night with the lamps lighted may require that the dynamo have a greater output than for one that is driven under usual conditions. The addition of electrical accessories sufficient to make a load on the system greater than it was designed to handle is not a good reason for increasing dynamo output, and doing so under these conditions will usually result in permanent damage to the electrical equipment.

In some cases the output adjustment is rendered easy of use by the repairman or driver of the car and the makers may furnish instructions for altering the charge rate for different conditions. In other cases, and the number of these is increasing, the adjustment is made at the factory, and the parts are then sealed so that this adjustment cannot be changed without breaking the seals. In these cases, breakage of the seals will result in the maker's guarantee becoming void.

As a general rule the dynamo output should be greater in winter than in summer because of the lower efficiency of the battery and the greater use of the lamps and starter at this time. During a long tour it may be advisable to lower the charge rate or to stop the charge altogether, by short circuiting the dynamo terminals, by opening a touring switch, if one is provided, or by removing a field fuse.

Considering the various methods of regulation from the standpoint of adjustment, the following points should be noted: It is not practicable to alter the dynamo output when reversed series regulation is used and this advice applies equally well to machines having compound field windings. The remaining classes of inherent regulation may usually be adjusted; the third brush by changing the position of the brush, and the iron wire system by changing the size of the wire used.

It is seldom advisable to attempt to make changes in adjustment of magnetically controlled vibrators that act to insert and withdraw field resistance, and in fact these types are not always made with provisions for adjustment. Adjustment is provided on systems that use carbon field resistance and the methods of adjustment have already been considered.

The dynamo output of the system that uses an ampere-hour meter is not directly adjustable, although the total net battery charge may be increased by moving the hand so that the contacts are not separated at such frequent intervals. The adjustment of the system using the rheostat operated by the plunger and coil is provided for by changing the weight in the plunger while a certain adjustment may be secured with the mercury well regulator by altering the resistance in series with the magnet coil.

Regulation depending on the action of centrifugal governors is always provided with means of adjustment. It should be borne in mind that these adjustments are very delicate and the slightest possible change in spring tension or weight position will have a considerable effect on the dynamo output.

CHAPTER VI

DRIVE METHODS AND STARTING SWITCHES

With the exception of the type of equipment which mounts the motor-dynamo directly on the engine crankshaft, all starting motors and some charging dynamos require a method of drive that allows their armature speed to exceed the speed of the engine crankshaft. This reduction is effected in the connections between engine and electric unit and may take any one of a wide variety of forms.

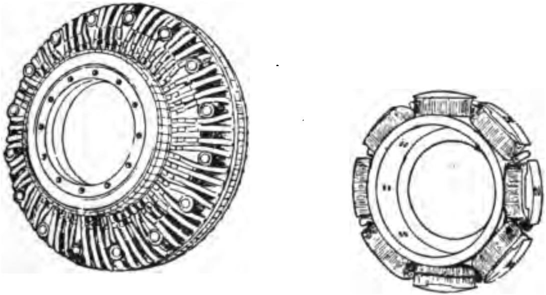


Figure 81.—External Armature and Fields for Motor-Dynamo (U. S. L.).

Mechanically speaking, the simplest possible drive is that used by the U. S. L. equipment. The electric unit, Figure 81, is a large size ring armature type of motor-dynamo having the armature fastened securely to the engine crankshaft. In some of the older types the armature revolves inside of the field coils, while in later models the armature diameter is great enough so that it is carried outside of the fields. In all cases the armature revolves and the fields are stationary. This machine acts as a compound-wound starting motor when the starting switch is closed. When the engine has started and is running under its own power the speed of the motor-dynamo armature becomes great enough to generate a voltage in excess of that of the battery, the electromagnetic cut-out closes and battery charging commences. The motor-dynamo is carried inside of the flywheel housing and the starting switch may be mounted on this housing or at some other point on the car. The regulating device and cut-out, or else a separate electromagnetic cut-out, will be found on the cowl or dash of the car.

A very common method of drive for either dynamo, motor or motor-dynamo is through straight spur or helical gearing from the engine timing or ignition drive gearing. In this case the electrical unit is mounted and driven in much the same way as employed for magneto drives and in many cases is driven by the same shaft that drives the magneto. The water pump shaft, when a pump is used, forms a convenient method of drive for the electric machine and this shaft is often used by mounting the motor or dynamo at the end of an extension from the shaft passing through the pump.

A satisfactory connection and a simple application is secured by connecting the electric units to the engine crankshaft by means of a chain of either the roller or silent type. The crankshaft sprocket may be at either end of the engine, although the front or starting crank end is usually used. In some cases the drive chain will be enclosed and possibly lubricated from the timing gear or crankcase compartment of the engine. In other applications the chains remain exposed and in plain sight.

Chain drive, gear drive or direct drive on the crankshaft may be utilized for either dynamo or motor because these types are well suited to carry loads as great as those imposed in engine starting and provide a positive connection. Drive methods that depend on friction between two surfaces can only be used for dynamo work because of the fact that they would not have sufficient surface available on an automobile to carry the power delivered by the motor in cranking. Belt drives have been used and are now used by a limited number of makers, and are satisfactory in all ways as long as the belt is kept tight enough to prevent excessive slippage and as long as both belt and pulley surfaces are kept clean and smooth. Dynamos have also been driven by means of a friction clutch, this application being made with the Entz motor-dynamo used on some models of White cars. With such a clutch in use sudden acceleration of engine speed does not place severe strains on the motor-dynamo drive parts.

A distinctive form of motor-dynamo drive has been used with a great many applications of the Delco system (Figure 82), this method allowing the motor-dynamo armature to run at a greater speed during engine starting than while generating current, yet providing a positive drive in each case. The single armature of the motor-dynamo has an extended shaft at each end. At the rear end this shaft extension carries one of a train of gears that mesh with teeth cut on the rim of the flywheel. With this flywheel gearing in mesh and with the motor-dynamo operating as a starting motor, the gear reduction is about twenty to one. The front end extension of the armature shaft is driven from another shaft, which is in turn driven from the front end of the engine crankshaft by means of gearing or chains. The connection from the front end of the armature shaft to the driving shaft is made through an overrunning or one-way clutch. This

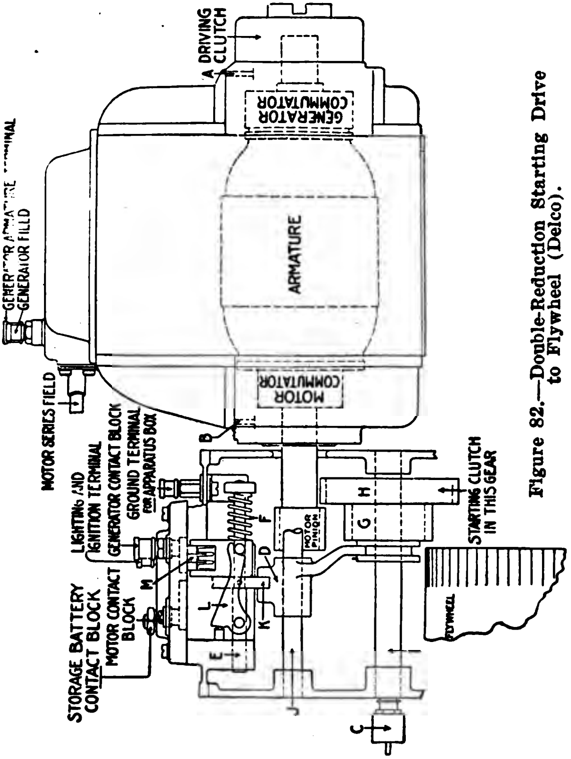


Figure 82.—Double-Reduction Starting Drive to Flywheel (Delco).

A, B, C—Lubrication.
D—Gear Shifting Yoke.
E—Switch Rod.
F—Switch Spring.
G—Flywheel Drive Gear.
H—Intermediate Gear.
J—Shifting Rod.
K—Spring Trip Collar.
L—Switch Latch.
M—Switch Terminals.

shaft and clutch will drive the armature shaft between two and one-half and three times as fast as the engine crankshaft runs, and as long as the armature shaft has no tendency to run faster under its power as a starting motor, the clutch will hold. Whenever the battery current is sent through the motor-dynamo, the armature shaft begins to turn and the overrunning clutch releases so that the armature shaft runs at the starting speed.

DRIVE RATIOS

Large dynamo output may be secured in either of two ways, high speed or large size. It is manifestly not practical or desirable to use dynamos of large size on automobiles because of the excessive weight and greater cost. The alternative of comparatively high speed is therefore resorted to. Dynamos generally are operated at from one to four times engine speed, the most common ratios lying between two to one and three to one. With a rear axle gear ratio of four to one and with thirty-four-inch diameter road wheels in use, the engine crankshaft will turn about forty revolutions per minute for each mile per hour of car speed. Therefore, at a car speed of fifteen miles per hour, the crankshaft will be revolving at about 600 revolutions per minute; at a car speed of twenty miles per hour, the crankshaft speed will be about 800 revolutions per minute, and so on for various car speeds. The types of dynamos in general use do not deliver their maximum or rated amperage at armature speeds much below twelve to fifteen hundred revolutions per minute, and it is desirable that this maximum output take place at driving speeds of about twenty miles per hour. It will be seen that in order to drive the armature at the required speed with the crankshaft running at about 800 revolutions per minute, a ratio of one and one-half or two to one will be required.

The conditions governing the selection of a starting motor drive ratio are the power that the motor will deliver at its armature shaft, the power required to start the engine crankshaft and engine parts in motion, and the power required to keep the crankshaft rotating at a speed sufficiently high to cause good carburetion and ignition. The engine conditions, in turn, depend on the bore and stroke of the cylinders, on the number of cylinders and on the excellence of design and workmanship in the engine. The power delivered by the starting motor depends on the amperage and voltage of the current flowing through it, on its speed of rotation, and on the excellence of workmanship and material. Power required by, or delivered from, rotating shafts is usually measured in foot-pounds, one foot-pound being the power required to lift a weight of one pound through a distance of one foot.

From three to four times as much effort is required to start an average engine from rest as is required to keep it in motion after being started, and the maximum power that the motor will deliver must be selected with the starting torque in mind. The word ''torque'' means a twisting or turning force, and as the powers being dealt with here are of this class, the measurements can most conveniently be given in this way.

The number of foot pounds torque required by several commonly found sizes of engine is given in the following table and will give a good idea of the work that the starting motor is called upon to do.

Bore	Stroke	No. of Cylinders	Running Torque	Starting Torque
3¾	4	4	20	82
3¾	6¾	4	34	125
3¼	4½	6	25	95
3½	5¼	6	32	120
3¾	5¼	6	40	140
4	5½	6	43	155
5	7	6	88	245
3¼	5¼	8	35	130
3	5	12	45	156

While the engine specifications selected in the table are those of well-known makes of cars, this has been done only for the comparative value of the figures, and does not necessarily represent the exact conditions that would obtain with a certain engine of a given make because of the variables in manufacture.

Depending on the size and design, typical starting motors will deliver from three to eleven foot-pounds torque with current flow between two and three hundred amperes. Taking an average case of a starting motor capable of delivering six foot-pounds torque, it will be seen that for the medium-size engines listed in the table, the gearing must provide a reduction of from seventeen to one up to twenty-five to one in order that this six pounds torque at the armature shaft may be multiplied to produce the 100 to 150 pounds torque required to start these engines from rest. It will be found that a majority of starting motors in use are provided with reductions that fall between these two limits.

From the running torques given in the table it will be seen that the average engines will require from twenty-five to forty-five foot-pounds of torque to keep them in motion. If a gear reduction of twenty to one is selected, the torque required for running will be divided by this reduction so that the starting motor will only have to deliver between one and one-quarter and two and one-quarter foot-pounds at the armature shaft after the engine has been started. The amperage required to accomplish this will be much less than that called for in starting from rest, and with starting motors of usual design will range from sixty to one hundred and fifty amperes. This amperage will allow the starting motors to attain armature shaft speeds of from 1200 to 3000 revolutions per minute. These speeds, with the reduction of twenty to one, will give a running speed for the engine crankshaft of from sixty to one hundred and fifty revolutions per minute. The speed required will vary with different engines, and it will be necessary to select a starting motor that will attain the required speed through the gear reduction in use while developing sufficient power to keep the engine in motion at that speed. Crankshaft speeds between seventy-five and one hundred and fifty revolutions per minute are satisfactory in practically all cases, although engines are driven at higher speeds in many installations.

The drive ratios selected for use with motor-dynamos do not depend on the same factors as those for separate units, because of the fact that the machine must usually operate at the same ratio for generating current as for starting the engine. As a general rule the armature shaft is made to revolve from two and one-half to five times as fast as the crankshaft. The power of the motor-dynamo as a starting motor must, therefore, be considerably greater for a given speed than that of separate units.

Various combinations of chains and gearing are used to obtain the necessary ratio of speed between the starting motor armature and the engine crankshaft. In the case of installations driving to the crankshaft direct, some form of double reduction will generally be used with separate starting motors, because in order to secure a ratio as great as twenty to one, or even ten to one, with a single reduction, the size of the driven gear or sprocket would be excessive. In order to use a single pair of gears or sprockets and obtain a ratio of twenty to one with an armature shaft gear or sprocket one and one-half inches in diameter, the driven member would have to be twenty times this diameter, or thirty inches, which would, of course, be impossible to use. To overcome this difficulty, a double reduction system is used with which a part of the total reduction is taken care of in each set of gears, or part in a set of gears and the remainder by chains with sprockets of different sizes.

When it is realized that two separate reductions of four to one will give a total reduction of sixteen to one, the problem is seen to be simple of solution, and the drive parts will be of very moderate diameter and still secure the desired ratio of drive. (See Figure 83.) When such a double reduction is used with chains for the final drive to the crankshaft, the primary reduction gearing is usually carried on or in the starting motor housing, one side being connected to the armature shaft and the other side to the sprocket on the outside of the housing to which the chain attaches.

Double reduction systems may consist of sets of spur gears very similar to those used in the change speed gearing of the car, and in some applications, notably older models of the Wagner systems, planetary forms of gearing have been used successfully. The ratio that corresponds to low speed in driving a car is then used for starting purposes, while the direct drive is used when the machine acts as a dynamo—the equipment in question being a single armature motor-dynamo. A number of makers have used a small spur gear running inside of a large ring gear with internal teeth. This method gives a great reduction in speed within a small overall space.

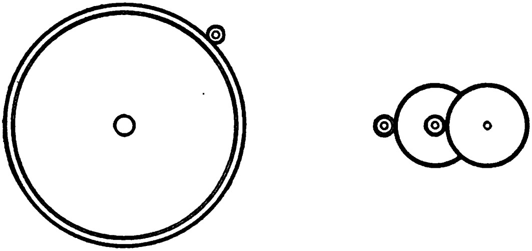


Figure 83.—Single Reduction (Left) and Double Reduction (Right) Giving Same Drive Ratio.

A single reduction is oftentimes used when the gear on the armature shaft drives to teeth cut on the rim of the flywheel. With a flywheel seventeen inches in diameter and an armature shaft gear one and one-half inches in diameter, the reduction will be approximately twelve to one, which will answer in almost all cases. Even with flywheel gearing the double reduction system is often used, the primary reduction being much the smaller of the two and taking place in gearing carried in or near the starting motor housing. This is shown in Figure 82.

While the drive to the flywheel or a drive to the engine crankshaft is the method usually employed for the starting motor, other systems are also in use. In the case of machines known as "double-deck," with the starting motor mounted above, below or at one side of the dynamo, the drive from the starting motor armature shaft to the main drive shaft, through which the engine drives the dynamo, provides a reduction that allows the starting motor to operate at six or more times the speed of the dynamo shaft, which, with the generally found dynamo reduction of two to one up to three to one, will provide a total reduction of from twelve up to twenty to one. (See Figure 84.)

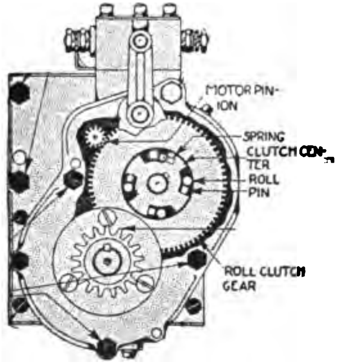


Figure 84.—Drive Parts for Double-Deck Motor and Dynamo (Gray & Davis).

The starting motor does not always drive direct to either the engine crankshaft or to the flywheel, but may be so connected that it drives first into the transmission or clutch shaft. With the clutch engaged, the countershaft in a sliding gear transmission will revolve and be positively connected to the engine whether the gearing is in any one of the forward or reverse speeds or is in neutral. In some applications the starting motor is carried on the transmission housing or alongside of the housing, and drives through gearing to the transmission countershaft, thence through the clutch to the engine. This method allows of locating the starting motor in a convenient place when the room under the engine hood is so limited that mounting there would prove difficult.

Another method of starter drive is that found with a worm gear drive from the starting motor to the clutch shaft between the clutch or flywheel and the transmission housing. By placing the starting motor transversely across the length of the car, a worm fitted to its armature shaft may be made to drive a worm gear fitted to the clutch shaft, and inasmuch as worm gearing may be built to give a very great reduction in speed, a suitable drive is secured by means of a single reduction.

DRIVE METHODS

In order to allow separate starting motors to drive the engine during cranking and then to be released so that they are not driven at excessive speeds by the engine, a number of exceedingly ingenious devices have been used. It is not uncommon for the gasoline engine to operate at crankshaft speeds as high as 2000 revolutions per minute. With a positive connection between starting motor and engine, and a gear reduction of twenty to one, this would cause the starting motor armature to revolve at 40,000 revolutions per minute, which is, of course, impossible, because the centrifugal force acting on the armature would destroy the motor long before any such speed could be attained, even were the engine capable of furnishing sufficient power to do the work.

Bendix Screw.—A very commonly used system is that known as the Bendix drive or inertia pinion (Figure 85). By this method the armature shaft gear is automatically meshed with teeth on the flywheel as soon as the motor armature shaft starts to revolve, and then, as soon as the engine speed is high enough for the flywheel rim speed to exceed that of the armature shaft gear, the gear is instantly thrown out of mesh. Surrounding the extended armature shaft is a sleeve free to move on the shaft but connected to the shaft through a coiled spring having one end fastened to the armature shaft and the other end fastened to the sleeve. On the outside of this sleeve is cut a coarse multiple screw thread, and a small gear with a correspondingly threaded hub is carried by the sleeve. As the shaft is turned, the gear will travel back and forth along the threaded sleeve just as a nut would travel along a bolt if the bolt were turned while the nut remained stationary. The starting motor is mounted in such a position that the sleeve gear is in mesh with teeth on the flywheel rim

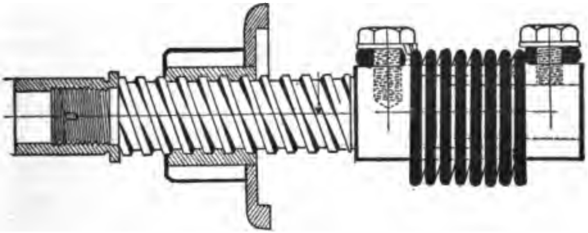


Figure 85.—Bendix Drive; Screw, Spring and Pinion.

when it is at one end of the threads, and is completely out of mesh with the flywheel when at the other end of the threads.

With the engine and starting motor idle, the small gear is out of mesh with the flywheel. Just as soon as current is sent through the motor the armature shaft turns and, through the coiled spring, causes the sleeve to turn. On one side of the gear is a weighted flange, and because of this weight the gear does not commence to revolve at once, but rather travels along the threads of the screw on the sleeve. This action brings the gear in mesh with the teeth on the flywheel either instantly, or, if the teeth meet end-on and do not slide into mesh, the coiled spring allows the sleeve to turn on the armature shaft enough to bring the teeth into position for meshing.

When the small gear has traveled far enough on the threaded sleeve to be in full mesh with the flywheel teeth, one side of its hub has come against a shoulder on the sleeve and it can travel no farther. The gear must then revolve with the sleeve, and because of the resistance of the flywheel to motion, the spring coils tighter still. When the spring is tightly coiled, the full power of the starting motor, together with the power stored in the coiled spring, acts to place the flywheel in motion, and the engine is cranked by the starting motor until it starts and runs on its own power.

As soon as the engine starts, the speed of the rim of the flywheel causes the small gear to revolve much faster than the starting motor has been driving it, and because it travels faster than the motor shaft and sleeve, it begins to travel along the threads in a direction that takes it out of mesh with the flywheel teeth. This change of direction is brought about because when the motor first started, the armature shaft and sleeve traveled faster than the small gear, while now the small gear is traveling faster than the armature shaft and sleeve. This action sends the gear out of mesh without causing the starting motor to attain any excessive speed. Should the starting switch be again closed with the engine running, the small gear will travel toward the flywheel and strike the rapidly turning teeth on the flywheel, and its speed will thereby be increased to such an extent that it again travels away from the flywheel. The weight on one side of the small gear that acted to prevent the gear from revolving with the threaded sleeve now performs another important function by making the gear bind on the threads through the overbalancing action of the weight on one side. This binding prevents the gear from again meshing with the flywheel teeth.

Overrunning Clutch.—In a large number of systems the starting motor drives the engine through an overrunning clutch that will allow the starting motor to drive the engine shaft as fast as it is capable of doing, but will allow the clutch to release whenever the engine tends to drive the starting motor. The principle involved is similar to that used in the bicycle coaster brake in which the rider (represented by the starting motor) might pedal the bicycle as fast as he possibly could, but with which no speed of the bicycle (represented by the engine) could cause the rider to pedal faster. In fact, the rider could stop pedaling altogether and allow the bicycle to run, just as the starting motor can come to rest and allow the engine to run.

The construction of an overrunning clutch is shown in Figure 86. The clutch consists of two principal parts, the outer ring *A* and the clutch center *B*.

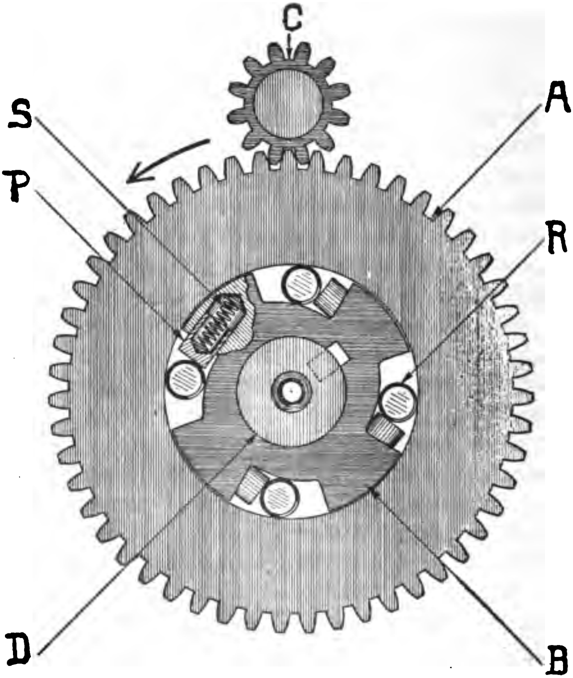


Figure 86.—Overrunning Clutch.

A—Driving Ring.
B—Inner Member.
C—Driving Pinion.
D—Driven Shaft.
P—Plunger.
R—Roller.
S—Plunger Spring.

The outside circumference of the ring *A* carries gear or chain teeth or a drive shaft, and is driven from the starting motor. In the construction shown, the starting motor drives the ring in the direction of the arrow. At several points around the inner part of the clutch are slots in which rollers are placed. The roller is continually pressed against one end of the slot by the small plunger and spring, and it will be seen that rotation of the outer ring in the direction of the arrow will wedge the rollers between the ring and the center part of the clutch. With the rollers thus tightly binding the two parts together, the inner part will be rotated by the ring and in the same direction as that of the ring. The center part of the clutch is fastened to the shafting or gearing that cranks the engine.

With the power of the starting motor applied to the pinion *C*, the outer ring and center section will turn together just as soon as the rollers lock in place. The locking is practically instantaneous, so that cranking commences at once. The starting motor will continue to revolve the engine crankshaft until the ignition takes place and starts the engine under its own power. The engine will now drive the center of the clutch in the same direction as during the cranking operation, but, of course, at a much greater speed. The center part of the clutch now rotates much faster than the ring, and, in fact, the ring and starting motor can stop entirely because of the fact that rotation of the center part in the direction of the arrow tends to roll the rollers back toward the plunger and spring end of the slot, thereby allowing clearance and release of the wedging action between the two parts of the clutch. No amount of power applied to the center of the clutch so that it rotates in the direction of the arrows will cause the rollers to wedge, and the engine can increase in speed without any effect on the starting motor.

Rushmore Starting Drive.—A novel system of gear meshing is shown in Figure 87, this being the method applied to Rushmore and Bosch-Rushmore systems. In the idle position shown at *1*, the armature of the starting motor is held out of line with the pole pieces by the coiled spring *S*. On the opposite end of the armature shaft is carried the small spur pinion which will mesh with the ring gear *F* on the flywheel. The starting switch has two active contacts, which are made, one after the other, when the switch button or handle is moved. On the first contact the battery current flows through the fields and causes their cores and pole pieces to become strong electromagnets which act on the iron of the armature core to draw the armature with its shaft and the spur pinion quickly and powerfully to the left, thereby meshing the pinion with the flywheel gear. During this first contact a resistance is in the starting motor circuit so that but

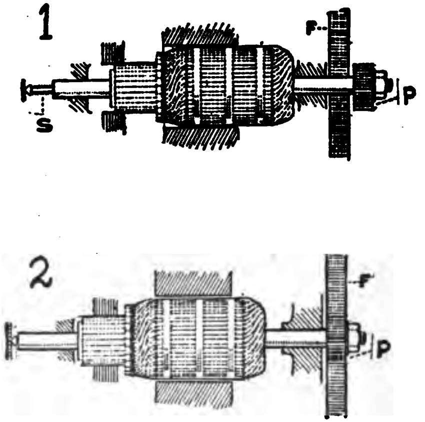


Figure 87.—Gear Meshing of Rushmore Starting Motor.

a part of the full battery current can flow, and most of this current passes through the fields only, because of a low resistance by-pass for the armature current. The small flow through the armature causes its shaft and the pinion to rotate slowly so that the meshing of the gears will be accomplished without trouble. The pause on this first switch contact is just long enough to allow gear meshing, and then the full battery voltage and current is applied to the starting motor through the second contact, which cuts out the resistance and armature current by-pass. Cranking then takes place, and as soon as the engine takes up its cycle of operation, the flywheel gear rotates the small pinion at a high rate of speed. This high speed causes the motor to become momentarily a dynamo, with the result that at the moment when it generates battery voltage, there is no further flow of battery current through the motor. With no flow in either direction, the fields are demagnetized and the tension of the coiled spring throws the gears out of mesh. Thereafter, the small flow of current that would be required to keep the armature in motion, should the starting switch remain closed, is not sufficient to draw the armature endwise and mesh the gears again.

Westinghouse Magnetic Gear Shifts.—In addition to a mechanically operated system and other applications using the Bendix screw, Westinghouse equipment has been furnished with gear-shifting devices and starting switches operated by powerful electromagnets or solenoids (Figure 88). Passing through the starting motor armature shaft is a sliding rod which carries the spur pinion for flywheel meshing at one end and the core of a solenoid winding at the other. This rod is free to slide endwise, but must turn with the armature shaft. In series with the starting motor circuit is the winding of the solenoid, and when the current for the starting motor passes through the winding the core is pulled back, with the result that the spur pinion, which has helically cut teeth, is meshed with the flywheel gearing. The gears are normally held out of mesh by a coiled spring, and when the pull necessary to start the engine is no longer required, the solenoid is demagnetized to such an extent that this spring pulls the gears out of mesh.

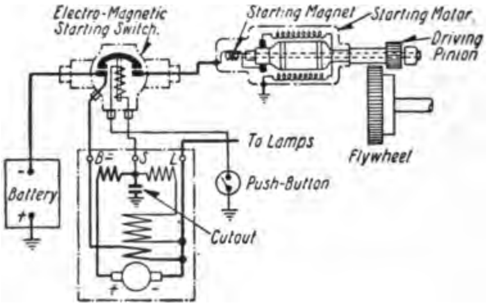


Figure 88.—Magnetic Starting-Gear Meshing System (Westinghouse).

Double Reduction Systems.—A system of gear-meshing which has been very generally used with slight modifications by a number of makers is illustrated in Figure 89. The starting motor *M* has its armature shaft keyed and extended at *D*. The pinion *P* may slide along this shaft, but turns with it because of the squared construction. Pulling the rod *R* in the direction of the arrow will slide the pinion *P* into mesh with the flywheel ring gear *F* by means of the yoke *Y*. At the same time that the gears are fully meshed, the starting switch contact piece will have closed the circuit between the contacts *S*, being moved by the arm *A*. The starting motor will then crank the engine in the usual way. An overrunning clutch is usually incorporated in the starting motor housing or in an intermediate gear between armature shaft and the pinion *P*.

In case the gear teeth should met end on, they would not mesh, and the following action would take place:

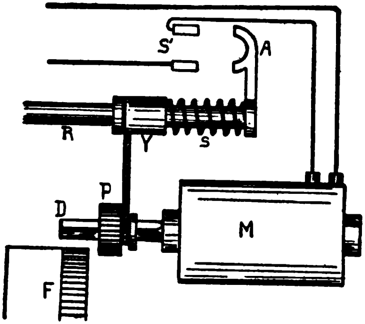


Figure 89.—Starting Drive with Spring Release.

A—Moving Contact of Switch.
D—Motor Armature Shaft.
F—Flywheel.
M—Starting Motor.
P—Motor Pinion.
R—Starting Pedal Rod.
S—Release Spring for Pinion Yoke.
S'—Switch Contacts.
Y—Gear Shifting Yoke.

The rod *R* is free to slide through the upper end of the yoke *Y*, except for the action of the coiled spring *S*, which holds the yoke against the collar shown on *R* and just at the left of *Y*. If the rod is pulled, the pinion *P* will first come up against the flywheel gear *F*, and then if *P* and *D* can move no farther, the coiled spring will be compressed against *Y*. Because of the fact that the rod *R* is moving regardless of the yoke, the arm *A* will cause the contact piece of the starting switch to close the circuit and the starting motor will commence to revolve. The smallest part of a revolution of the armature shaft will bring the gear teeth into meshing position, and the tension that has been placed on the spring *S* by the continued movement of the rod *R* will instantly snap the pinion into full mesh with the flywheel gear, and cranking will take place.

In the system just described, power is not applied to the starting gearing in any way until the gears are fully meshed or until the spring has been sufficiently compressed to mesh the gears instantly with the first application of power. Another method which will be found in a number of applications causes the pinion to revolve quite rapidly, but with very little power, so that the moving teeth will quickly find a meshing position with those on the flywheel rim. A system of this type, in which power is momentarily applied to the pinion and then withdrawn, is shown in Figure 90. The starting switch now has two pairs of contacts, *P* and P^1, and *Q*. Between the contacts *P* and *Q* is a resistance *R*. The pinion is normally held out of mesh with the flywheel teeth and in the

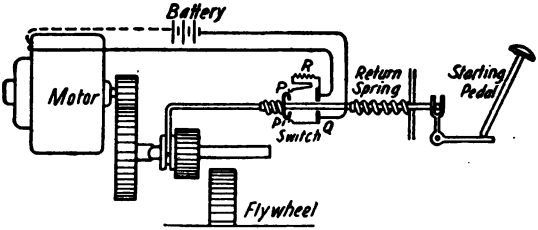


Figure 90.—Starting Switch with Resistance.

P, P'—Preliminary Contacts. R—Resistance.
Q—Main Contacts.

position shown. When the starting switch button is pressed down, the pinion is moved toward the flywheel, but before the teeth are in a meshing position the starting switch contacts *P* and P^1 are connected by the moving contact piece on the switch rod. Battery current then flows through the motor and to the switch contact through the resistance, which reduces the flow of current, and by way of the contact *P*, contact piece and contact P^1, to the wire and back into the battery. The armature shaft and pinion are then revolved at high speed with little power, and as the switch rod continues to move the pinion toward the flywheel, the contact piece in the switch leaves the contacts *P* and P^1, so that the pinion is left spinning but without any current passing through the motor. The revolving pinion slides into mesh with the flywheel teeth, and by the time the gears are fully meshed, the contact piece in the switch has come against the main contacts *Q*, thus closing the circuit between the battery and motor without the resistance, so that the full battery voltage is used for cranking. As in the last case considered, an overrunning clutch is carried in the starting motor housing or in one of the intermediate gears.

Another method somewhat similar to those just described is found in equipments that apply a small amount of power to the motor armature so that the pinion is kept revolving until the gears are in mesh. An example of this method is found in Delco motor-dynamos, whose armatures and fields each have two windings, one for generating and the other for starting. When the ignition switch is closed, the battery current is sent through the dynamo fields and armature windings so that the armature and the small starting pinion is caused to revolve slowly and with very little power. As soon as the gears have been meshed, the full battery voltage is applied for cranking.

While most of the double-reduction gear applications described operate with an overrunning clutch between starting motor and crankshaft or flywheel, this unit is not absolutely necessary. A number of applications of Bijur systems have been made in which the sliding pinion is carried on the extension of the armature shaft and meshes with the flywheel teeth without the use of a clutch. In this case it is very essential that the starting switch be released as soon as the engine starts to fire, as otherwise the motor armature will be driven at dangerously high speeds.

STARTING SWITCHES

A majority of starting switches now in use may be divided into two classes, one of which (Figure 89) provides only a single pair of contacts that allow the full battery voltage to be impressed on the starting motor when the switch is closed, and the other one of which (Figure 90) uses two pairs of contacts in such a way that the battery and starting motor circuit is first completed through a resistance and then, with further movement of the switch, this resistance is cut out and the full battery voltage and current is used for cranking. The forms that these two types may take are many, and will vary with the make of equipment and with the model in almost all cases. Their construction is quite simple, both electrically and mechanically, and may be easily understood from a superficial examination. The contact points and the contact arms are built large and heavy so that they are able to carry heavy amperage without undue resistance or heating. The starting switch terminals are oftentimes used for the attachment of lines used for the lighting and charging circuits, so that the wiring leading to and from the starting switch may apparently be complicated because of this use of its terminals for junction points.

A single pair of contacts will always be used with systems having a Bendix screw or inertia pinion for starting drive. The single contact switch may also be used with many of the systems having an overrunning clutch. A double contact switch is used when it is desired to start the pinion in motion before meshing takes place, and will be used when no overrunning clutch is provided.

Magnetic Switches.—Several Westinghouse systems have made use of a starting switch that is operated by an electromagnet, the electromagnet being energized when the driver presses a button conveniently located at some point within his reach. The connections for such a switch are shown in Figure 91, and the operation is as follows: When the pushbutton is pressed, current flows from the grounded side of the battery to the button, through the button and to the electromagnet winding in the starting switch. From the magnet in the switch the current passes to the dynamo, then back through a connection made in the switch housing, and to the other side of the battery. The pull of this electromagnet in the switch attracts the armature of the magnet, and this armature carries the contact piece for the main switch contacts. With the main contacts closed, the current flows through the switch and to the starting motor. In series with the starting motor circuit is a solenoid

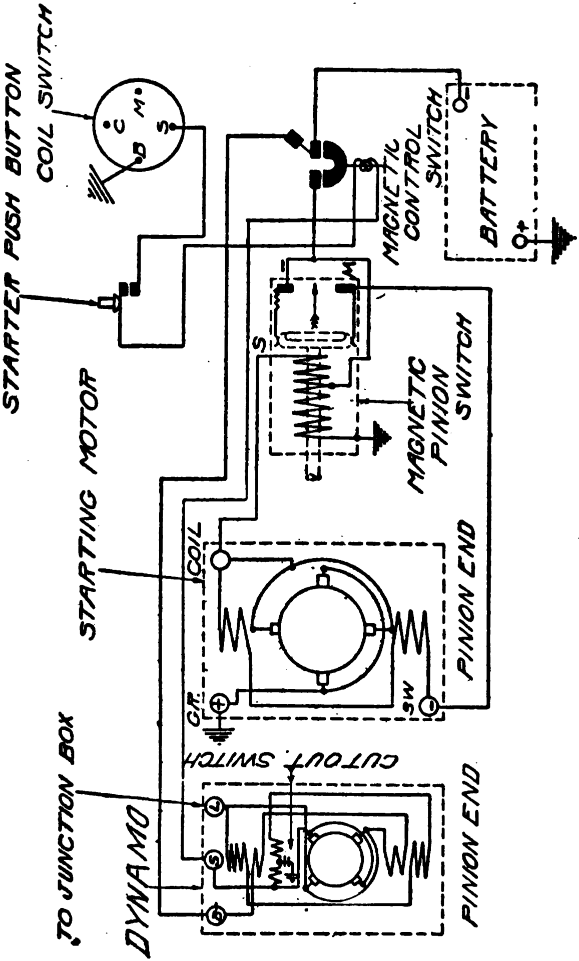


Figure 91.—Magnetic Starting Switch and Gear Shift (Westinghouse).

through whose windings passes the core attached to the gear meshing rod, and the gears are brought into mesh by the action of this solenoid. The starting button causes the switch magnet to become energized, and the flow thus allowed to pass through the switch energizes the solenoid so that the gears are meshed. As soon as the engine starts to run, it drives the dynamo, and the current from the dynamo that passes to the battery flows in a direction opposite to that allowed by closing the starting button with the dynamo idle. Because of this reversal of current, the electromagnet in the switch is demagnetized just as soon as the cut-out closes, and the starting switch contacts are immediately opened. No amount of pressing on the start button can cause the starting switch to close and the gears to mesh with the engine running for the reason that the current for this operation cannot pass to the electro magnets while the cut-out is closed.

Motor Brush Switches.—A movement of the starting motor brushes, either one or both of them, has been used with many of the Delco systems, and with some others, to take the place of a switch. By this method (Figure 92), the starting motor brush arm is pivoted so that the brush may be drawn away from the commutator surface or allowed to rest on it. With the engine idle the brush is held away from the commutator by linkage from the starting pedal connections. With the usual construction an extension on the starting brush-arm is used to complete the connection between the dynamo brushes and the battery circuits. When the ignition button is closed, or when the electromagnetic cut-out contacts are closed by mechanical connections from the starting pedal, the battery current flows through the dynamo armature and fields and causes the armature and starting pinion to revolve so that gear meshing can take place. When the starting pedal and its connections have moved into such a position that the gears are in full mesh, the connections in the motor-dynamo housing allow the movable starting motor brush to drop onto its commutator, thus completing the battery circuit through the starting coils on the armature and through the series field windings. When the starting

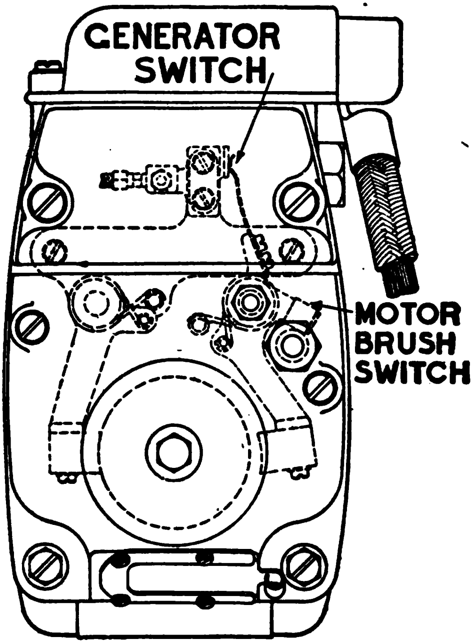


Figure 92.—Starting Switch Action with Movable Brush (Delco).

brush drops onto its commutator, the movement of the brush-arm causes the connection from the dynamo brushes to the battery to be broken so that during the cranking operation no current can flow to or from the dynamo windings. As soon as the engine has started, the pedal is released and the gears pass out of mesh at the same time that lifting of the movable starting brush breaks the starting circuit while re-establishing the dynamo connection with the battery lines so that charging can take place.

Motor-Dynamo Switches.—Motor-dynamos may be divided into two classes, one of which will include those machines that complete the connection between battery and electric unit for starting and then allow this connection to remain closed while the motor-dynamo speed becomes high enough to cause battery charging. (See Figures 59 and 60.) The other class includes those machines that complete the connection for starting through one of the usual forms of starting switch and complete the charging connection through an electromagnetic cut-out. The latter system is always used with installations that use a high starting voltage and a comparatively low charging and lighting voltage, because it would be manifestly impracticable to allow a machine that generates a low voltage to remain connected to the battery with the battery sections so connected as to produce a high voltage, as used in starting.

The connections made by switches which establish a circuit that is maintained for both starting and charging have been described in Chapter V under "Cut-Outs." Practically any of the types making a single contact for starting may be used with dual voltage equipments.

Commutating Switches.—The type of switch used with motor-dynamos that use a starting voltage higher than the charging voltage is known as a commutating switch, because it changes the connections between the battery and the electric machine to allow for either of the functions to take place. With such switches in the idle or running position, the sections of the battery are connected in parallel or multiple, so that the voltage of the whole battery will be no greater than one section and will be correct for lighting and charging. With the switch in the starting position, the battery sections will be connected in series with each other, and the voltage of the whole battery will be equal to the voltage of one section multiplied by the number of sections used.

The connections made by the switch used with Splitdorf-Apelco systems, having twelve-volt starting and six-volt lighting and charging, are shown in Figure 93. The two positive terminals of the battery are connected to the switch terminals marked +*A* and +*B*, while the negative terminals of the battery sections are connected to terminals —*A* and —*B-D*. Eight contact points are carried inside of the switch, four of which are connected, two and two, in the running position, while the remaining four are likewise connected, two and two, during cranking. With the contact members in the running position, the flow of current is as follows: From the positive terminal of the motor-dynamo, as a dynamo, through the cut-out and to the starting switch terminal marked +*A*, by means of the wire *12*. From this terminal the current flows through one line directly to one of the positive terminals on the battery and also through the internal connections of the switch and through the contact member to the switch terminal +*B* and to the positive terminal of the other battery section. From the

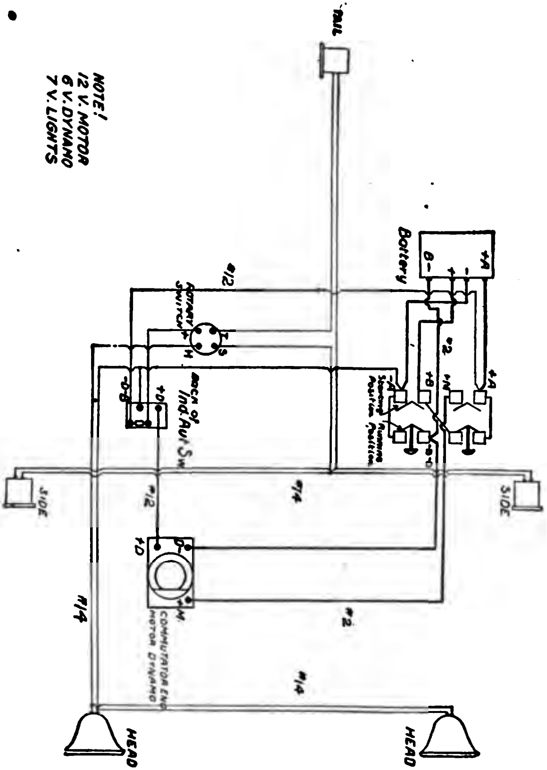


Figure 93.—Connections for Commutating Starting Switch (Splitdorf-Apelco).

—*B-D* switch terminal, which carries the line from one of the negative terminals of the battery, another line runs directly to the negative dynamo terminal of the motor-dynamo, while the connection from the switch terminal —*A* and the other negative terminal of the battery comes through the internal connections of the switch and the other contact member to the switch terminal —*B-D*, where it joins the current from the other battery section in its path to the dynamo. It will thus be seen that both sections of the battery are connected with the dynamo, with both positives together on one side and both negatives on the other side of the starting switch.

With the switch contact members in the starting position, the flow of current is as follows: From one of the positive terminals on the battery to switch terminal +*A*, then through the switch contact piece to terminal +*M*, and to the starting motor terminal on the motor-dynamo. Passing through the starting motor fields and armature of the motor-dynamo, the current returns to switch terminal —*B-D*, and to one of the negative terminals on the battery through the other line attaching to this same switch terminal. Passing through this section of the battery, the current flows to switch terminal +*B*, through the switch contact member and to terminal —*A*, thence back to the negative terminal of the battery section from whose positive terminal the tracing of the flow commenced. It will thus be seen that the flow is through each section of the battery, first one and then the other, also through the starting motor, so that both sections of the battery and the starting motor are in one series circuit.

The connections made by the Simms-Huff commutating switch are shown in Figure 94. The sliding contacts move from right to left in the position illustrated, and are drawn in full lines for the running and charging position and in dotted lines for the starting position. In the charging position one of the positive terminals of the battery connects with switch terminal *1*, and through the wire *A* to terminal *4*. The other positive terminal of the battery connects with switch terminal *5*, and through the sliding contact piece with terminal *4*. Both sides of the battery are thus joined at *4*, and from this terminal a line leads through the cut-out (not shown) to the positive terminal on the motor-dynamo. The negative side of the motor-dynamo is grounded, and one of the negative terminals of the battery is also grounded directly. The other negative terminal of the battery is attached to switch terminal *2*, and by means of the sliding contact piece to terminal *3*, which is grounded. Both battery negatives are, therefore, connected together, and both positives are likewise connected. The positives are connected to the positive side of the dynamo and the negatives are connected with the negative side of the dynamo through the ground connections.

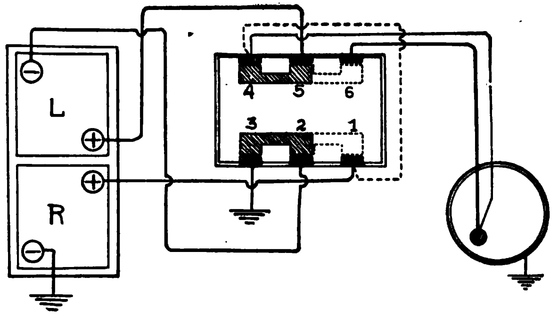


Figure 94.—Commutating Starting Switch with Sliding Contacts (Simms-Huff).

With the switch contacts in the starting positions, the current flow starts from the positive terminal of the battery section marked *R* and passes to the switch terminal *1*. Then through the contact piece in the switch to terminal *2*, and back to the negative side of battery section *L*. After flowing through section *L*, the current passes to switch terminal *5* from the positive side of the battery section, and through the contact piece in the switch to the starting motor terminal on the motor-dynamo. Passing through the motor, the current flows to ground and through the metal of the car returns to the grounded negative terminal of battery section *R*, having completed a series circuit through both battery sections and the motor-dynamo.

CHAPTER VII

INDICATING DEVICES AND TROUBLE LOCATION

Because of the fact that almost any trouble that may come to the electrical equipment will cause some change in current flow or pressure, the subject of indicating instruments is closely allied with that of trouble location. As mentioned in Chapter I, there are six divisions into which most all of these instruments may be divided, these divisions being the ammeter, the voltmeter, combined voltammeters, current indicators, moving targets, and pilot lamps.

Ammeters.—Ammeters may be built upon any one of a number of different principles, and they may be built cheaply or made very expensive. Regardless of the type or quality of the instrument, the flow of current which conforms to the definition of one ampere remains the same, and because of this fact the various constructions will not be treated at length. As a general rule, the construction of an ammeter and a voltmeter does not differ materially according to whether the instrument is to measure amperes or volts. In the case of the ammeter, the flow is allowed to continue without appreciable resistance, and it is this flow of current that is measured. With the voltmeter the flow is practically stopped because of the very high resistance of the instrument, and this stoppage allows the pressure that is acting in the circuit to be measured. Even in the case of the voltmeter (for all types in general use) there is some passage of current, and the construction and principles of action are the same as for the ammeter, the sole difference being in the amount of flow allowed to pass through the instrument.

Ammeters are provided with a pointer or hand which moves from side to side with increase or decrease of flow through the circuit in which the instrument is placed. The pointer moves across a scale graduated in amperes or fractions and multiples of amperes and having a zero point at or near the center of the graduations. The pointer will move one way from this zero point with flow of current in one direction, for instance, into the battery, and will move in the opposite direction from the zero point when current flows in the opposite direction, as would be the case during battery discharge. This type of instrument is known as a "zero center" ammeter (Figure 95). If the meter was built in such a way that the hand stood at one side of the scale when at zero, it would only measure the flow of current in one direction, and would not be suitable for attachment on the car.

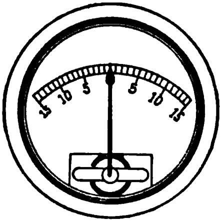


Figure 95.—Zero Center Ammeter.

Ammeter scales may be marked "Charge" on one side and "Discharge" on the other side of zero, and when marked they should be so connected to the battery circuits that the hand will swing to "Discharge" when current is flowing out of the battery, such as would be the case with lamps turned on and the engine standing idle. The hand will then swing to "Charge" when current is flowing from the dynamo into the battery.

An ammeter should be placed on a car and so connected that it will measure all of the current flowing into the battery from the dynamo, and so that it will measure all current leaving the battery except that used for starting. An ammeter sufficiently great in capacity to measure the large flow during the cranking operation would have a scale too coarsely divided to measure the small currents used for charging and lighting. It is, therefore, necessary to find a wire on the car that carries all of the charging current and all of the lighting and other accessories' current, but none of the starting current. This may usually be done by following either one of the large battery cables until a smaller line branches from this cable. The ammeter may then be attached in this smaller line and just as close to the large cable as possible. Provided the wire selected carries all of the lighting and charging current and none of the starting current, the ammeter will then indicate the net charge and discharge other than for starting.

Should the charging wires and the lighting wires be connected to the large cables from the battery at different points along these heavy cables, it will not be possible to attach an ammeter to show both charge and discharge. This will also be the case with a great many motor-dynamo systems in which no line can be selected that carries both charging and lighting currents that does not also carry the starting amperage. It will often be found possible to attach an ammeter so that it will show charge into the battery, but no discharge for the lamps and other current-consuming devices. It will also be possible to attach an ammeter to one side of a separate dynamo so that the dynamo output will be indicated, this method, however, being of comparatively little value because it is the current entering the battery that is more essential than that furnished by the dynamo. In the absence of special directions for attaching an ammeter it will be necessary to follow the wiring as described or else to examine a wiring diagram of the car or system in question until a line is found that does not carry the starting current but that does carry the currents whose value it is desired to measure.

With an ammeter connected, some lamps should be turned on and the direction in which the needle moves noted. If the scale is marked "Charge" and "Discharge," the needle should move toward "Discharge," and if it does not do so, the wires should be removed from the ammeter terminals and interchanged with each other. In case the face of the meter is not marked, the connections should be made in such a way that the needle will swing to the right of zero for charge and to the left for discharge.

Voltmeters.—A voltmeter may be attached between any two points or any two wires whose difference in pressure or voltage it is desired to measure. While an ammeter should always be placed in series with the circuit whose flow it is to measure, the voltmeter is very seldom placed in series for the simple reason that its resistance is so high that practically no current flow could take place with the instrument so connected. In connecting an ammeter, the circuit is broken at some point and one side of the meter connected to one end of the circuit, while the other side of the meter is attached to the other end of the circuit. No such procedure is necessary with a voltmeter, it being only necessary to place the wires from the voltmeter on the points whose voltage is to be measured, and the needle of the instrument then shows the voltage difference existing at that time.

When voltmeters are mounted as part of the equipment of a car, they are attached to the positive and negative side of the circuit between battery and dynamo, and usually on the dynamo side of the cut-out (Figure 96). A voltmeter draws such a very small flow of current that the loss from this use may be neglected while the engine is running. However, it would not be advisable to connect a voltmeter directly to the terminals of a battery and allow it to remain there, because even such a slight flow of current continued without any interruption would eventually discharge the battery wholly or partially. To attach a voltmeter correctly, the car's wiring should be examined and the line from the dynamo to the cut-out found. One side of the voltmeter should then be attached to this line, either at the dynamo or cut-out or any other convenient point. The other side of the

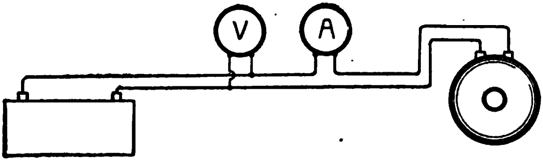


Figure 96.—Voltmeter and Ammeter Connections.
A—Ammeter. B—Voltmeter.

voltmeter may then be attached to any other wire or terminal between battery and dynamo, provided that this second point of connection is of opposite polarity from the first. The meter will then indicate the charging voltage at all times while the engine is running fast enough to close the cut-out.

Voltmeters are sometimes attached directly to the battery so that they indicate the battery voltage or the voltage at the battery terminals at all times. Such a connection should not be made unless the meter is known to be of a type designed for such use, and should then be used in accordance with instructions given by the makers of the car or of the electrical equipment.

Voltammeters.—Because of the similarity between the voltmeter and the ammeter, it is quite possible to use a single instrument for both purposes. The voltammeter consists of a single movement which is fitted with suitable terminals and resistances to allow its use in either capacity. Voltammeters are usually provided with one terminal for use in voltage measurements, with one terminal for use in measuring amperage, and with one terminal for use with either one of the two first mentioned, regardless of whether volts or amperes are being measured. A voltammeter may be provided with a switch which is turned to take voltage readings, or may simply require that the connection be made on the voltmeter terminal. While such combinations are in common use as portable testing instruments, they are seldom found attached to the automobile as a permanent part of the electrical equipment.

Indicators.—These instruments have faces or dials showing three conditions—"Charge," "Off," and

"Discharge"—the "Off" position corresponding to zero on the ammeter. They are constructed on the principles employed in the ammeter, but do not measure the exact amperage. They may be so constructed that attachment in the main battery circuit is possible and so that all charging current and all discharge, including that for starting, passes through them. With the engine running fast enough to cause charging, and with the lamps and other current-consuming devices out of use, an indicator should show "Charge." With any current being drawn from the battery the instrument should show "Discharge." (See Figure 97.)

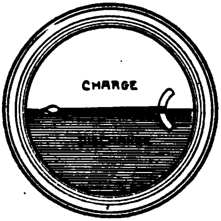


Figure 97.—"Charge-Off-Discharge" Indicator.

Targets.—Because of the fact that some part of the electromagnetic cut-out must move when the connection between dynamo and battery is completed, it is possible to use some visible marker or target attached to the cut-out as a current indicating device. It should be understood that because the cut-out is closed it does not necessarily mean that the battery is being charged. The lamps turned on at that time may be consuming all of the current generated, or the cut-out itself may be defective and not completing the circuit to the battery, although apparently doing so.

Pilot Lamps.—Dash lamps connected in such a way that they light up when the cut-out closes are used with some installations. The same caution applies in a certain measure as given for the target, that is, that this type of indicator does not necessarily prove that the battery is being charged. A pilot lamp connected between dynamo and battery is a fairly reliable indication, however, and because of the proportion of charging current that passes through it, the lamp should never be allowed to remain out of its socket or burned out.

It should be borne in mind that all types of current-measuring and indicating devices are subject to troubles that render their indications of little or no value. Ammeters and voltmeters should be watched to make sure that they indicate zero when the engine is idle and all lamps out. If there is an error either way, this error should be allowed for in making readings with the instrument. It may happen, and often does happen, that the magnet used in these instruments becomes damaged or too weak to perform its work, and in this case the meter will become very sluggish and its hand will tend to stay in whatever position it comes to rest until the current flow is high in value. While the higher-priced instruments have provision for resetting the hand or dial at zero, the low-priced voltmeters and ammeters are valueless when damaged, and it is economy to replace them with new ones.

STARTING AND LIGHTING TROUBLES

Faulty operation of the various units may appear in one of two forms, either electrical trouble or mechanical trouble. Mechanical troubles include those caused by loose, broken and worn parts, by incorrect assembling and lack of proper care and upkeep, such as lubrication and cleaning. Electrical troubles include the faults that prevent the current from traveling in its proper paths and from doing the work that is expected of it. Almost all electrical troubles may be placed under one of four headings, namely: (1) open circuits, (2) circuits having abnormally high resistance, (3) short circuits, and (4) the modification of short circuit called a "ground." (See Figure 98.)

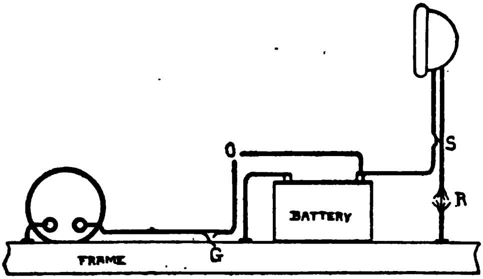


Figure 98.—Troubles in Wiring System.

G—Accidental Ground.
O—Open Circuit.
R—High Resistance.
S—Short Circuit.

An open circuit occurs whenever a wire breaks or becomes detached from one of its terminal connections so that the current can no longer flow. An open circuit may also be caused by an improperly made or dirty connection in which the current-carrying surfaces do not make proper contact with each other. Any fault that prevents the current from flowing because of the lack of a complete path or circuit away from and back to the battery is said to result in an open circuit, or simply an "open."

High resistance may result from poorly made or dirty contacts in which the current-carrying surfaces are in partial contact. The area of the conductors is so reduced in size that all but a small amount of current is prevented from passing the point of high resistance. Wires that are partially broken through and wires that are too small for the work they must do will cause an abnormally high resistance. Dirty, pitted or corroded contacts in the dynamo, cut-out or regulating parts will cause high resistance, and, in fact, any fault that results in a partial stoppage of current flow through a circuit that should be complete and of low resistance will bring this trouble about.

A short circuit is established whenever an accidental current-carrying path occurs in a circuit at a point that allows a flow from the battery when there should be no flow, or that allows the current to leave the battery and return to it without passing through the lamps or other devices that are designed for current consumption. The success of any electrical installation depends on the flow of current being kept within the conductors designed to carry it, and should the insulation fail or should exposed parts come into contact in such a way that an improper flow is allowed, the result will be a drain on the battery, failure of the dynamo to generate, failure of the starting motor to act, or a failure of almost any of the electrical units, depending on the point at which the short-circuit occurs.

A ground is a form of short-circuit that is established through the metal work of the car. With the one-wire system, or the grounded return system, an accidental ground will occur whenever a current-carrying conductor comes into electrical contact with a part of the metal of the car. With a two-wire, or insulated return system, it is necessary that both sides of the circuit come into electrical contact with the metal of the car. This fault is rarely met with in the two-wire system because of the fact that the metal work of the car does not ordinarily act as a conductor for one side of the circuit.

Indicating Instrument Faults.—Because of the fact that ammeters, voltmeters, etc., are primarily designed to tell what is happening and to aid in locating trouble, it should not be assumed that these units themselves are free from error. Outside of trouble caused by open, short or grounded circuits and circuits of high resistance in the wiring and terminal connections of these instruments, they may develop trouble within their mechanism. Should an ammeter be subjected to a current much greater than it is designed to carry, such as would be the case were an ordinary instrument connected in the starting circuit, the current-carrying coils would be burned out and the meter would have to be rebuilt before further use could be made of it. An ammeter or voltmeter of the permanent magnet type, such as is ordinarily employed, will lose its accuracy if exposed to heat, sudden jars or a strong magnetic field. The first and most apparent effect of such a happening will be a sluggish action of the indicating hand. The hand will move slowly from place to place on the dial, and will not return to zero until jarred, if at all. It is quite frequently found that a meter hand does not return to the zero point when current flow or pressure is removed, yet the action may be satisfactory in all other ways. To overcome this difficulty, to which all meters are more or less subject, high-grade instruments are provided with a "zero center" adjustment by which the tension of the springs controlling the movement may be changed or by which the dial itself may be moved until the position is again correct.

When an ammeter or voltmeter is in proper working order, the hand should remain at zero with one or both of the wires removed from its terminals. Should there be an error at this time, the number of amperes or volts should be noted and allowed for in future readings. The hand should move quickly from point to point and should come to rest within a reasonable time.

Should an indicating target such as is attached to an electromagnetic cut-out fail to indicate charge with the engine running at a fair rate of speed, trouble in the cut-out is indicated, or else a failure in the dynamo or other parts of the charging system that prevents the cut-out from closing. Failure of a pilot lamp to light indicates that the lamp bulb is broken or burned out or else that one of the cut-out troubles mentioned above is present.

LIGHTING SYSTEM TROUBLES

The lighting system of the car consists of the lamps, together with the necessary wiring, switches, fuses, circuit breakers and junction connections. Lighting trouble that is not a result of lack of charge or voltage at the battery will be found in one or more of the above mentioned units.

In case of failure to light, the bulbs themselves should be examined to make sure that they are not broken and that the filaments are not burned out. Should the lamp have been fitted with bulbs designed for a voltage lower than that used on the car, the filaments will be burned out, while bulbs designed for a higher voltage than that used will not light at all. The average life of a good tungsten filament bulb should be from 100 to 300 hours, but low-efficiency or cheap bulbs may become dim or may burn out in much less time.

It is quite possible for dirt, loose wire strands or faulty construction to cause an accidental short-circuit in the bulb base or in the socket into which the base fits. Such a fault will probably result in allowing such a heavy flow of current at the defective point that heating will result, and at the same time all the other lamps on that circuit or line will burn dimly or not at all. It may be found that the small contact points on the bottom of the bulb base do not make contact with the plungers or springs in the socket. The springs may be bent up slightly or the contact points may be extended by the addition of a drop of solder to each. If the socket contains spring plungers, they should be pressed down and examined for binding or dirt that will cause sticking when the bulb base is pressed home. If the plungers can be pressed down and then remain down, it indicates that the springs have become broken or are binding, and a new socket is the most satisfactory remedy. The interior of the bulb sockets should be kept free from dirt and foreign matter of all kinds because the result may be either a short-circuit or an open circuit for that particular lamp. It is customary to provide the lamps with connectors into which the wires fasten and which complete the circuit by means of plungers or pins that fit into holes in a second part of the connector. The same remarks respecting dirt and poor connections apply to these outside connectors as to the bulb sockets. Should the lamps flicker and occasionally go out altogether, the wiring at the sockets and at the connectors should be examined for loose strands. In case a part of the copper is found exposed, it should be wrapped with insulating tape to prevent a repetition of the trouble caused by the movement and jarring of the car while in motion.

Should trouble manifest itself in one or more lamp groups and no faults be found with the lamps or bulbs, the wiring for the affected portion of the equipment should be carefully examined to locate possible short, open or grounded circuits. The insulation should be perfect along the entire length of each wire, and any worn places should be well wrapped with tape. The points at which the wires turn around corners, and the points of fastening by means of cleats on the metal work, should be given a careful inspection, and the conductors should be moved wherever possible while the lamp switches are turned on to test for broken wires underneath the insulation. In case the candlepower of the lamps has been increased, or in case additional lamps or other accessories have been added to any of the circuits, it is quite possible that the wire originally used may be too small for the added load. Lamp circuits should be made with wire not smaller than No. 14 gauge, and 12 gauge will be safer in case of any added load. Wires of opposite polarity should not be run so close together that they touch unless they are bound together with tape or fasteners, because of the chafing that will result. In case it is necessary to run lines through places where they will become wet or oily, the wiring should be enclosed in metal conduits or by circular loom, and the openings through which the wires enter and leave the protecting coverings should be tightly taped.

A large number of cars are equipped with bus-bars, junction blocks or boxes and distribution panels at the terminal posts of which several lines meet and are connected together (Figure 99). These points of connection may develop short circuits between the several cables of different circuits, or may contain accidental grounds on the metal work of the car. Loose strands of wire should be carefully guarded against, and all such wire ends should be fitted with metallic terminal pieces that hold all the wire strands by means of the solder used in making the attachment. It is often found that dirt, oil or moisture enters these connection boxes through the wire openings, and in case the junctions are located at points exposed to such trouble, it will be well to tape each line where it enters the enclosed portion of the junction.

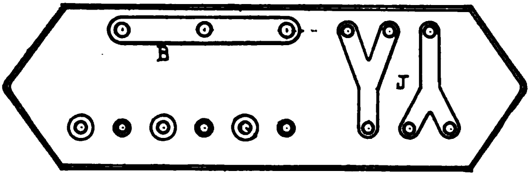


Figure 99.—Distribution Panel.
B—Bus-Bar. J—Junctions.

In the case of a car equipped with fuses in the lighting or charging lines, these units should be examined to make sure that the circuit can be completed from end to end. The fuses are designed to protect the equipment against short circuits and overloads, and should a fuse be found burned out, the line leading away from it should be examined for the short circuit that is almost sure to be found. It will do no good to replace a fuse in a lighting circuit until the cause of its burning out is found and remedied, because a new fuse will only suffer in the same way as the old one as soon as the faulty conditions reappear. Fuses should never be replaced with others of a higher capacity than those originally furnished with the car, because the protection to the circuits and other units will no longer be present. The final result of such replacement will probably be damage many times more serious and more costly than the new fuse of the proper size would have been. Such advice applies even in stronger measure to replacement of fuses with lengths of copper wire. This is the poorest kind of economy and should never be practiced. It will oftentimes be found that a failure to complete a circuit through a fuse is due to poor contact of the fuse with its holding clips or due to poor contact of the clips and terminals with the wire ends that are attached at these points. A minute piece of foreign matter between the fuse and the clip will prevent a flow of current, and before deciding that the fuse is burned out, it should be turned around in the clips once or twice to remove any such particles. The clip ends should be pressed together until they hold the fuse firmly, and the screws that hold the wire terminals should be turned down tight.

The contact points of circuit breakers should give no trouble because they are so seldom called upon to do any work. In case of high resistance or an open circuit in lines protected by these devices it can do no harm to examine them and to clean the contacts by drawing strips of very fine emery cloth between them while held closed. In case a circuit breaker opens, it indicates an overload on that line, and this overload, whether caused by short circuit, ground or improper connections, should be located before the breaker is closed. Some types of circuit breakers will open and close rapidly with a buzzing noise as long as the trouble is present, and the spring tension or adjustment should never be changed to overcome an accidental leakage of current.

Should the lamps flicker or go out entirely, it is possible that the trouble will be found in the lighting switches. These switches are simple in construction, and their action may be understood in each case by an examination. The contacts should be examined to make sure that they close their respective circuits and to make sure that the leaves are not bent or binding and that the surfaces are clean and bright. The moving parts of the switch may have become loose so that they make only an intermittent connection while the car is in motion, and all of the internal parts should be moved by hand to determine whether this trouble is present. The terminal studs and nuts should be watched for looseness or breakage, either external or internal, and in case of any doubt as to the proper connections being made, a wiring diagram for the car being handled should be consulted.

CHARGING SYSTEM TROUBLES

Any failure of the dynamo, cut-out, regulating device or charging wiring will result in the specific gravity of the battery electrolyte becoming abnormally low, and in the voltage of the battery falling below two for each cell. As far as the wiring is concerned, the same advice as that given for the lighting circuits may be applied to this case. Other troubles may come from faulty conditions of the dynamo brushes, commutator, armature or fields, or from faults in the cut-out and regulator.

In case a test at the dynamo with an ammeter shows no flow of current, or if a voltmeter test shows no voltage being generated, it may be assumed that parts inside of the dynamo housing are at fault. While either the cut-out or regulator or both of these units may be carried inside of or on the dynamo housing, they are not properly a part of the dynamo, and will be given separate consideration.

With the brushes exposed, their holders should be examined to see that the pivoted arms are free to swing back and forth, and that sliding brushes do not bind or wedge in any position. Such binding of the brush itself may be remedied by carefully dressing the sides with a fine file. Attached to each brush or to the brush holder is a short length of flexible wire called the brush pigtail. These small wires must not be broken and their connections must be clean and tight at each end.

Either the brush itself or else the brush holder is held by a coiled or flat spring so that the brush bears on the commutator surface with a tension just sufficient to cause the brush end to make good contact at all armature speeds. These brush springs should not be bent, loose, broken or binding, and should have sufficient tension to cause a good firm connection to be maintained, but should not be set up so tight that there is danger of the brush cutting into the commutator surface.

In all types of dynamos the brushes or their holders are insulated from the remainder of the dynamo by means of bushings, washers and sleeves. These insulating parts must not be broken or cracked, and if covered with oil or carbon dust should be thoroughly cleaned. In the case of grounded return systems, the ground connection is made through the pig-tail, but the brush itself is insulated.

The end of the brush must exactly fit the curve of the commutator in those machines that provide brush contact on the curved outer part of the commutator. In case the contact surface of the commutator is formed from the flat side of the ring, the surface of the brush must then be perfectly flat and bear evenly at all points on the segments that pass under it during armature rotation. The brush end may be fitted to the commutator by drawing strips of thin fine-grain sandpaper between brush and commutator with the sand side toward the brush, this procedure having been described in the chapter on dynamos and shown in Figure 21.

The brushes should be replaced with new ones when worn down nearly to the holder or spring, and in making such a replacement the safest method is to secure the new brushes from the makers of the car or the makers of the electrical equipment. As a general rule it may be said that none but carbon or carbon composition brushes should be used, because of the fact that brushes made from copper or copper alloys tend to cut into the commutator surface and cause serious damage and rapid wearing. Even with carbon brushes in use, care must be exercised to see that the material is very fine and of smooth grain. Brushes that are light gray in color and that show a granular or rough surface are not safe to use.

Should the brushes be found in good condition, the commutator should be examined next. Its surface should be very smooth and should preferably have a glazed appearance and a dark brown color. In case the surface of the segments is found to be dirty, scratched, rough or pitted it may be dressed with fine sandpaper by following the method described in the chapter on dynamos. Excessive sparking will cause burning and pitting of the commutator surface, and this sparking will usually be found to result from the use of brushes of improper material or from the fact that the brushes do not make good contact with the commutator.

The segments forming the commutator should be examined to see that none of them are projecting above the surrounding surfaces and that all are up even with the curve of the commutator. These troubles may be corrected by turning the commutator in a lathe, but if the condition is the result of loose segments or fastenings, the armature should be sent to its makers for repairs. The small wires that connect the segments with the armature coils should be watched to see that they are unbroken and well insulated. Worn or broken insulation may be replaced by taping and then shellacing over the surface of the tape. If the connecting wires are broken they should be fastened in place with hard solder or silver solder.

The insulation between the segments should be below the surface of the commutator, and if found even with or above the surface of the surrounding segments, it should be dressed with some cutting tool such as described in the method given in Chapter II.

Armature and Field Testing.—In order to handle this class of work it will be well to secure a circuit tester of some form which will indicate by a flow of current when a circuit is complete through a certain path and when it is incomplete. A very satisfactory tester may be made by cutting one side or one wire of an ordinary drop-cord such as is used for shop and garage lighting. See Figure 100. Cutting one wire in this way will cause the lamp to go out, even though the switch be turned on, but as soon as the two ends of the severed wire are brought together, the circuit will be completed and the lamp will indicate this fact by lighting. These two free ends of one side of the circuit may be used as a tester by touching them to any two points between which it is desired to make a test. For example, with the wire ends touched to the two ends of a conductor that is completing its circuit, the lamp will light because the circuit is now made through the conductor being tested. If the conducting path is not complete, the lamp will indicate this fact by remaining dark. In case it is desired to know whether or not a certain wire is grounded, one of the test wires may be touched to the metal of the car and the other test wire to the wire being tested. Should the lamp light, it indicates that the wire being tested is in electrical con-

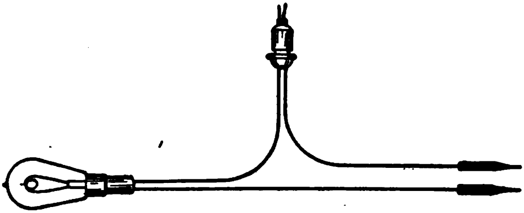


Figure 100.—Circuit Tester.

nection with the metal of the car and is therefore grounded.

The troubles most commonly found with armatures are burned out or broken windings and windings grounded to the core or armature shaft. With one end of the test wire touching any point on the surface of the commutator, the lamp should light when the other test wire is touched to any other point on the commutator. Should the lamp remain out with the connection made at any point, it indicates that the winding connected to the segment being touched is broken or that the segment of the commutator is disconnected from the armature windings. With one of the test wires attached to the metal of the armature shaft or armature coil the lamp should not light when the other end of the tester is touched to the commutator at any point on its surface. See Figure 101. Should the lamp light, it indicates that either the armature windings or the commutator segments are grounded. To remedy either of these conditions requires special equipment and experience and the work should be done by a shop able to handle it properly.

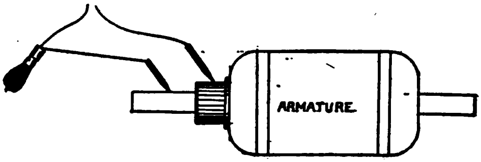


Figure 101.—Test for Accidental Ground.

In order to test the field windings for possible troubles it will be necessary to reach the terminals or connections that carry the leads for these windings.

In the case of straight shunt wound dynamos having an external regulator, one end of the field winding will attach to one of the dynamo terminals, while the other end of the winding will lead either to another dynamo terminal, to a ground connection or directly to one of the main brushes. In third-brush dynamos one end of the field winding attaches to the regulating brush and the other end to one of the main brushes or to a second field brush. In either of the above cases, lifting one or more of the brushes away from the surface of the commutator will usually serve to isolate at least one end of the field coils. The connections for compound wound dynamos, for dynamos with bucking coils or reversed series field windings and for motor-dynamos will vary according to the construction of the machine, and can best be found by examination and test or by consulting a wiring diagram that shows the internal connections.

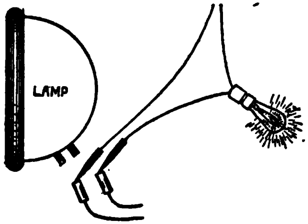


Figure 102.—Test for Open Circuit.

Troubles that occur in the fields may take the form of burned out or broken windings or connections, of disconnected terminal fastenings, or of ground connections made with the core or dynamo frame. It should be possible to secure a connection from one end of the field windings through to the other end with the drop-cord circuit tester and the lamp should light. Failure to secure such a connection indicates a broken or disconnected field circuit. With one of the test wires attached to the metal of the dynamo, the lamp should not light when the other end of the test wire is touched to either end of the field coil while the coil is disconnected from all other circuits and from the brushes and commutator. It should be noted that no circuit test, either to find whether a circuit is complete or grounded, is of any value unless the lines to be tested can be separated from all other connections during the test. Should any outside wiring be left connected, the circuit may be completed through another path than the one being tested and erroneous conclusions will be drawn in many cases.

The permanent field magnets used on some dynamos are subject to certain peculiar faults that will not occur with wound fields. These magnets will gradually become weaker and weaker with long continued use until they must be removed and remagnetized just as would the magnets of a magneto used for ignition. Permanent magnets must not be hammered or jarred violently, and at all times, while removed from the dynamo, the opposite poles should be joined with a small bar of iron or steel so that the path of the magnetic lines of force may be completed through this so-called "keeper." Should all of the magnets composing the set used on a dynamo be put on the machine with their poles placed in positions opposite to that originally occupied, the polarity of the machine will be reversed and serious damage to the battery will result if they are not changed immediately. Should part of the magnets be replaced in the correct position, but the remainder be reversed in position, the several members will oppose each other in action and the dynamo output will be greatly reduced if not prevented altogether. It is not good practice to mount permanent magnet machines on bases made from iron or steel because the lines of force from the magnet ends will pass to a great extent through the metal of the base rather than through the core of the armature, and the dynamo output will be reduced in proportion to the loss taking place.

Cut-out Care.—Manual or hand-operated cut-outs require the same care and attention as called for by any other type of switch. Electromagnetic cut-outs are of more complicated construction and are subject to a different class of faults.

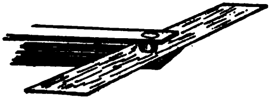


Figure 103.—Cleaning Contacts.

The contact points of an electromagnetic cut-out should be kept clean and bright and should meet evenly and over their entire surface when the cut-out is closed. Should plain surface contacts be found dirty or pitted, they may be cleaned by drawing strips of thin emery cloth between them while holding them lightly together. See Figure 103. This method of using the emery cloth will also restore the surfaces to such a form that they make full contact in case they have become out of line for any reason.

When the engine runs at a charging speed, the cut-out contacts should be closed by the action of the magnet, provided the dynamo is giving the necessary voltage. Failure of the cut-out to close when the dynamo is in good condition will usually be caused by loose or dirty connections of the wires on the cut-out terminals or possibly from a broken or burned out shunt winding in the cut-out magnet. If the cut-out closes, but does not complete the circuit for charging, the contacts should be examined and the terminal connections of the wires should be made clean and tight.

Regulation Trouble.—The characteristics and construction of the various systems of output regulation will be found described under their several headings in Chapter V. Their care will be described here in the same order and under the same names as used in the former description.

The reversed series field winding is not subject to any troubles that are peculiar to its regulating functions provided it has been properly designed and installed when the dynamo was built. This field winding is, however, subject to the same troubles that may be encountered with any shunt or series field and methods of locating such troubles have already been given.

The third-brush system adds nothing to the dynamo for regulating purposes except one or two additional brushes. These brushes require the same careful fitting that would be called for with any other current-carrying brushes and the field winding itself does not differ in any important particular from other shunt windings and may therefore be handled in the same way. The same remarks apply to those dynamos having compound field windings, inasmuch as in this case the entire regulating system is found in the series winding on the field cores.

The iron wire ballast coil of the Rushmore system of control must be securely held in place by its clips, just as would be the case for a fuse similarly carried. See Figure 104. The output is affected by the size of wire used and information necessary in making any changes called for has been given in Chapter V. The coil should be tested in case of trouble to make sure that the iron wire has not become disconnected and has not been burned out or broken. These troubles will cause the bucking coil to act at all times with a resulting drop in dynamo output.

Any form of magnetically controlled field resistance operating on the vibrating principle requires that the regulator contacts and terminal connections be given the same care as outlined for the electromagnetic cut-out. The contacts, when dirty, may be dressed by using very fine emery cloth drawn between them, and in this connection it should be noted that improper wiring of the controller may result in sending the charging current through the regulator contacts, which will result in rapid pitting and burning of the surfaces.

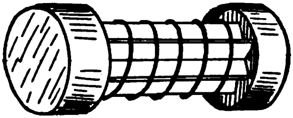


Figure 104.—Ballast Coil for Rushmore Iron Wire Regulation.

The systems that make use of carbon discs for field resistance require that the carbon pieces be cleaned occasionally by removing them from their holders and rubbing lightly on fairly rough paper. The end plates of the carbon piles should be cleaned with fine sandpaper.

The rheostats found with the Adlake and Vesta systems of control require cleaning of the contact segments at certain intervals. This cleaning may be accomplished by first wiping the surfaces with a cloth moistened in gasoline and then, should pitting appear, fine sandpaper may be used to remove the marks. The brushes should make good contact with the segments and their surfaces should be kept clean and smooth. The spring that holds the brush in place should have sufficient tension to ensure a good current-carrying contact at all times, but should not bind the contact arm. The plunger of the Adlake controller should move freely within its socket and may be cleaned with a gasoline moistened cloth in case of sluggish action.

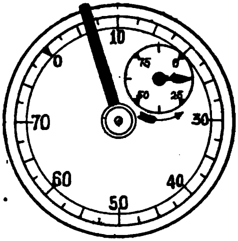


Figure 105.—Dial of Ampere-Hour Meter (Delco).

All forms of friction clutch governors operated by centrifugally controlled weights should have the contact surfaces of their clutches kept clean and free from dirt or oil. These surfaces may be cleaned with gasoline and a stiff brush. The weights should be securely held by their arms and should be tightened at the first sign of looseness. The spring tension adjusting screws should be turned down tight when properly adjusted and should be held in place by lock-nuts or other fastening devices.

The Delco ampere-hour meter, Figure 105, should have its contacts cleaned at long intervals. The only other care required is that the large hand be lifted up once every two weeks and turned twenty points in a clockwise direction. The hand should never be re-set past the number "70" on the dial, and if twenty points movement would do this, the amount of setting will have to be reduced.

STARTING TROUBLES

The starting system consists of the motor, the starting switch, the wiring and the driving parts. Electrical trouble may be present in the motor, switch or wiring and mechanical trouble may occur in the driving mechanism.

The troubles outlined under the heading of the dynamo in this chapter may also be found in the starting motor and their location and remedy will be cared for in the same way as in the case of the dynamo. The starting switch contacts may be making poor contacts because of wear, looseness or bending, or the contact surfaces may be dirty or pitted from sparking. The terminal connections of the large cables on the starting switch should be examined for loose wire strands, accidental grounds or short circuits, broken or loose fastenings. The wiring is subject to the same troubles as found in the charging or lighting circuits, but because of the heavy conductors and thick insulation used such faults will be of less common occurrence in the starting system than in other parts of the equipment.

The parts of the starter drive systems should be kept clean and sliding surfaces should be lubricated with heavy oil or by means of grease placed in the cups. This lubrication should be cared for at least every week if trouble is to be avoided. It may be found that drive shafts have become bent through binding or improper use of the starting pedal and in some cases it will be found that gear shifting and switch return springs are not heavy enough for the work to be done, especially on new cars before the parts have been fully worked in. Overruning clutches should be lubricated with vaseline or rather thin grease of good quality and the starting pedal should never be held in the starting position long enough to cause the clutch to be run at high speed. This will surely result in burning the grease and the final result will be a badly damaged or ruined clutch.

CHAPTER VIII

MAKES AND TYPES OF EQUIPMENT

Following the names of the well-known makes of automobile starting and lighting equipment will be found a brief description of the types of starting and lighting apparatus that have been made and marketed by these companies.

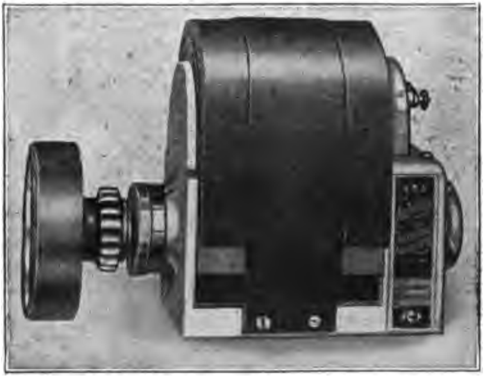


Figure 106.—Auto-Lite Dynamo with Constant Speed Governor.

AUTO-LITE

Early models of Auto-Lite equipment comprise a permanent magnet dynamo of the constant speed type, Figure 106, fitted with a slipping clutch governor at the drive end and carrying its electromagnetic cut-out underneath the magnets and just above the armature housing. This machine has been superseded by types that have electromagnetic fields carrying a compound winding with the series coil arranged to oppose the shunt, Figure 107, thus forming a machine with reversed series regulation.

Auto-Lite dynamos have carried an ignition breaker and distributor in some instances, but other combinations, such as motor-dynamos, have not been used. The starting motors are straight series wound units in all cases and, together with the dynamos, operate at six volts.

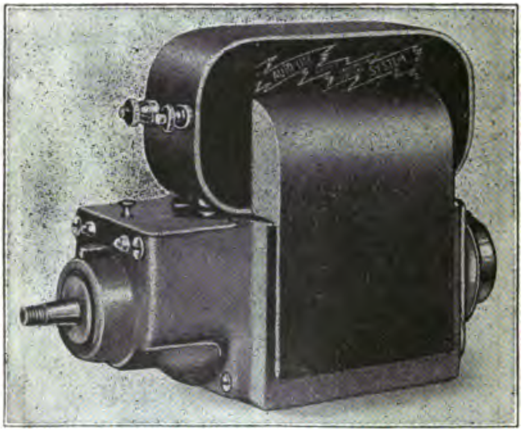


Figure 107.—Auto-Lite Dynamo Having Reversed Series Field Windings.

DYNETO AND ENTZ

Until recently all machines of these makes have been compound wound motor-dynamos operating at a constant ratio of speed with the engine. The electric unit is directly connected to the engine, usually by means of a silent chain, and is placed in electrical connection with the battery by means of a hand-operated switch, no electromagnetic cut-out being employed. These single-unit machines, Figure 108, have been made to operate with either twelve or eighteen volts.

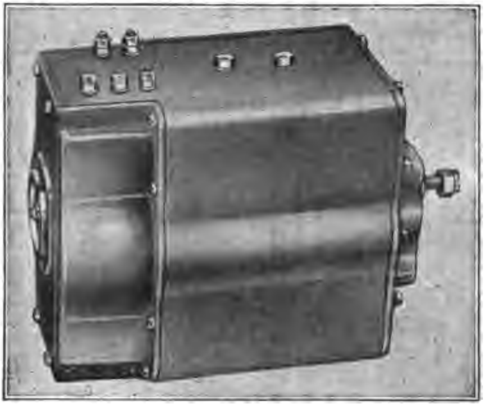


Figure 108.—Dyneto-Entz Motor-Dynamo.

A recent addition to the Dyneto line consists of a separate dynamo and a motor, both operating at six volts. The dynamo is connected with a separately mounted controller which contains an electromagnetic cut-out and a vibrating regulator that acts to insert a resistance in the field circuit when the amperage reaches a certain maximum determined by the adjustment of the regulator. The starting motor used with this system is a series wound machine conforming to the practice generally followed in such units.

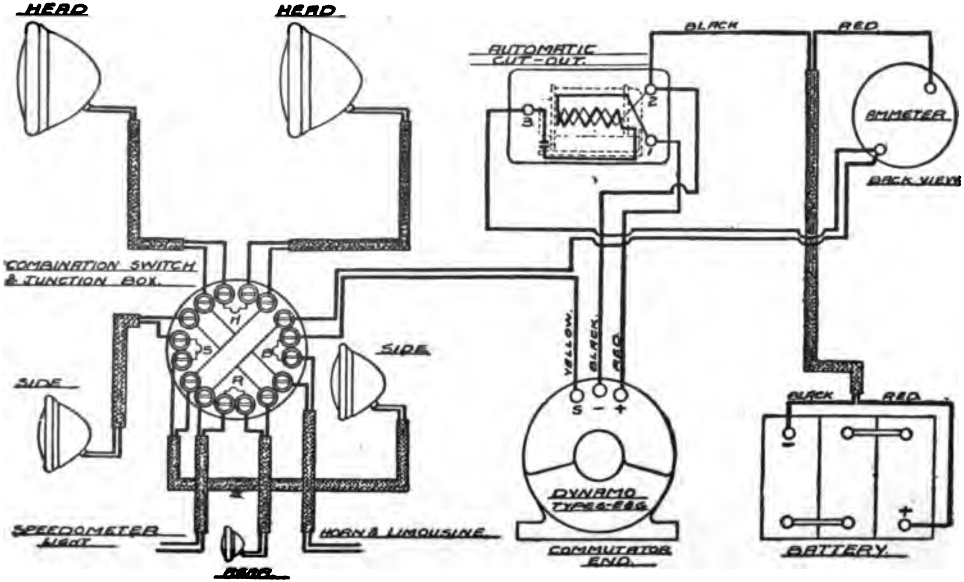


Figure 109.—Wiring for Gray & Davis System Having Constant Speed Dynamo.

GRAY & DAVIS

The first Gray & Davis equipments, Figure 109, included a compound wound dynamo fitted with a slipping clutch governor to limit the armature speed. The series winding of these machines carries the lamp current when any lights are in use, thus increasing the dynamo output in proportion to the load. An electromagnetic cut-out is mounted on the dash or at any other convenient point on the car, and the electrical devices may be wired on the ground return plan or by the use of a double-wire system throughout.

Later models of this make, Figure 110, use a dynamo of the shunt wound type having a vibrating regulator with field resistance and an electromagnetic cut-out mounted in one housing on top of or near the dynamo. The starting motors used with separate dynamos are of the series wound type in all cases and all units operate at six volts. Gray & Davis have recently added a single-armature motor-dynamo that carries the same form of controller as the separate dynamos just mentioned.

REMY

Remy equipment includes separate dynamos and motors, ignition dynamos, motor-dynamos, double deck machines and motor-dynamos with ignition parts mounted on the electric machine. With the exception of the twelve-volt motor-dynamo, all of the types make use of six-volt pressure for lighting, charging and starting. Either a third-brush system or else a vibrating regulator with field resistance have been used in a majority of installations. The third-brush machines, which class includes some of the double-deck equipment as well as separate dynamos, make use of an electromagnetic cut-out carried on the dynamo or mounted elsewhere on the car. The types using the vibrating regulator, Figure 111, combine the electromagnetic cut-out with the regulator in a

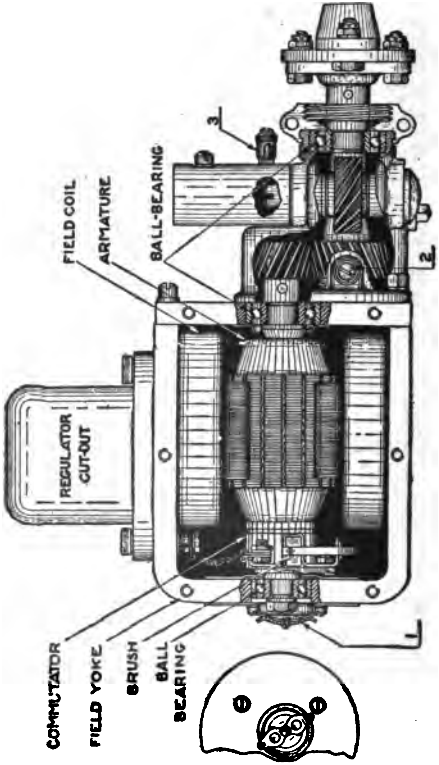


Figure 110.—Gray & Davis Dynamo with Vibrating Regulator and Cut-Out.

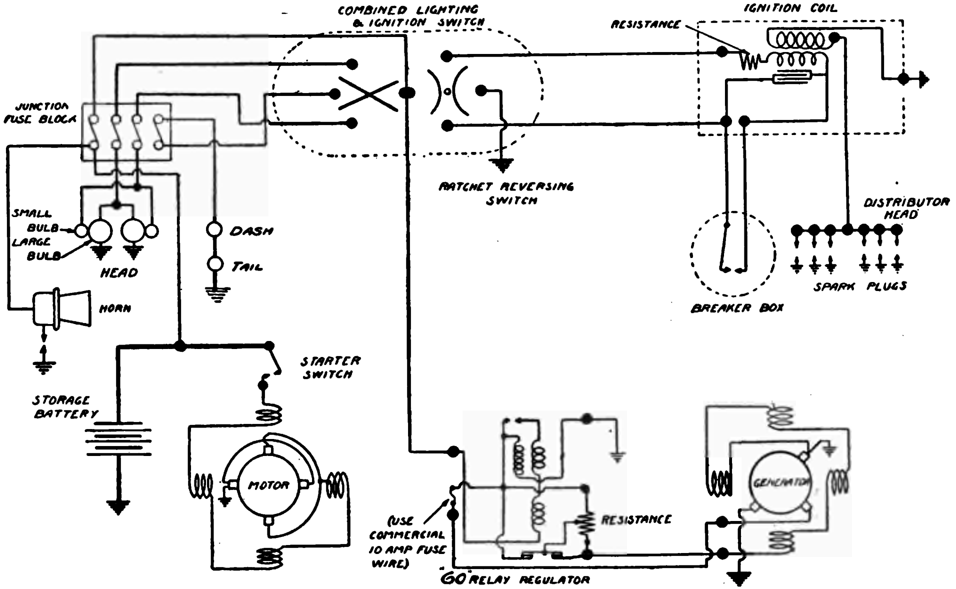


Figure 111.—Wiring for Remy System Having Vibrating Regulator and Cut-Out.

controller that may be carried above the dynamo or separately mounted.

Ignition-dynamos carry a breaker and distributor of the familiar magneto form at one end of the machine, and drive these parts from the extended armature shaft. In some cases a separate dynamo may be fitted with a vertical type of ignition breaker and distributor driven from the dynamo shaft. The starting motors are of the series wound type and may employ any one of several types of drive to the engine. The wiring for all units may be carried out on either the one or two-wire plan.

DELCO

The greater proportion of Delco equipment uses a compound wound motor-dynamo. Some of the more recent installations include separate dynamos having a shunt field winding and used in connection with a series wound starting motor. The earliest types consist of a single-armature motor-dynamo having one set of brushes for both starting and charging functions. These systems, Figure 112, are fitted with a twelve-cell battery of four sections, allowing twenty-four volts for starting and six volts for charging and lighting. These "6-24 volt" systems carry the ampere-hour meter regulator, described in Chapter V, and an electromagnetic cut-out.

All of the later motor-dynamo systems provide the single armature with two commutators, two windings and two pairs of brushes, one set of each being used for starting and the other for charging. These machines all operate at six volts and are built with the single-wire or grounded-return system in all cases. With some types of this class an electromagnetic cut-

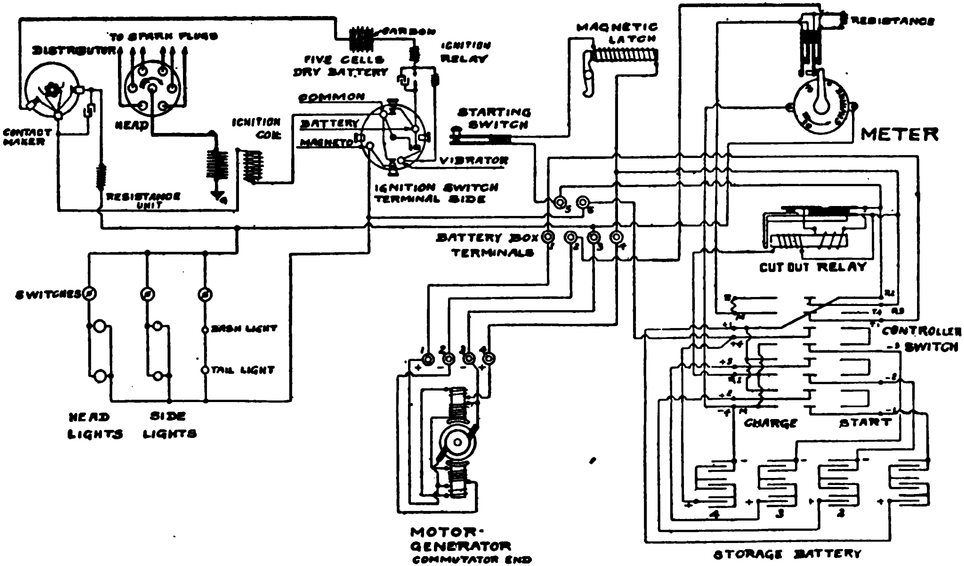


Figure 112.—Wiring for Delco System of the 6-24-Volt Type.

out is fitted, Figure 113, while others make use of additional contacts on the ignition switches for the purpose of connecting the motor-dynamo as a dynamo with the battery for charging. Regulating methods have included the reversed series system, a centrifugal governor, Figure 114, inserting a field resistance, a mercury-well type of voltage regulator or a third-brush control, Figure 115, for the shunt field current.

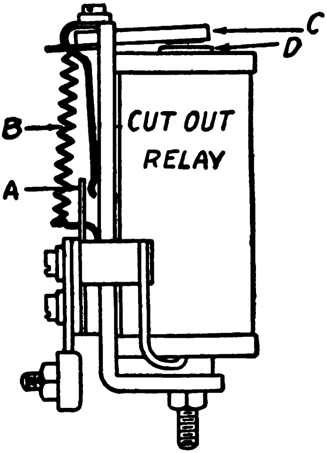


Figure 113.—Delco Cut-Out.

A—Contact Points.
B—Spring.
C—Magnet Armature.
D—Magnet Core.

DISCO

The most commonly used Disco equipment consists of a compound wound motor-dynamo direct connected to the engine by chains or gears. This unit is fitted with a controller comprising an electromagnetic cut-out and a vibrating regulator acting to insert a resistance in the shunt field circuit when the amperage

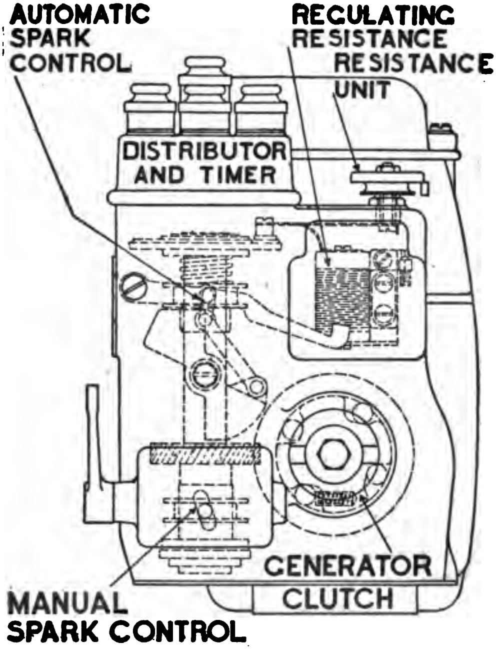


Figure 114.—Delco Centrifugal Governor and Field Resistance.

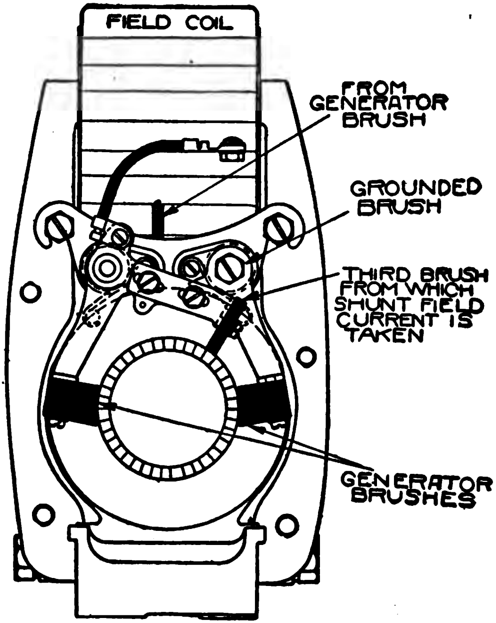


Figure 115.—Delco Third-Brush for Dynamo Regulation.

is at the predetermined point. Disco systems of the kind described operate at twelve volts and make use of a single-wire connection for all circuits.

WESTINGHOUSE

Three distinct types of Westinghouse dynamos are in use. The form first adopted is a shunt wound machine with an additional bucking coil, the flow through which is lessened in proportion to the candlepower of the lamps lighted while the dynamo is running. These dynamos carry an electromagnetic cutout at one end and may or may not be fitted with an ignition breaker and distributor at the other. Almost all dynamos of this class operate at six volts and cars using them generally are wired with a ground return system.

Twelve-volt motor-dynamos are also a part of the Westinghouse line, these machines being direct-connected to the engine at all times. The output is regulated by a third brush for the shunt field current and a separate electromagnetic cut-out may or may not be used.

Later models of Westinghouse apparatus include shunt wound dynamos with a self-contained or separately mounted controller consisting of an electromagnetic cut-out combined with a constant voltage vibrating regulator that inserts resistance in the field circuit when the voltage is at the correct point for battery charging. See Figure 116.

Separate starting motors are of the series wound type. They may be connected with the engine by means of a Bendix screw drive, by an electromagnetically operated starting switch and pinion shift, or by means of a two-contact switch with sliding gears that are revolved by the current sent through the motor by the first contact of the switch, and after

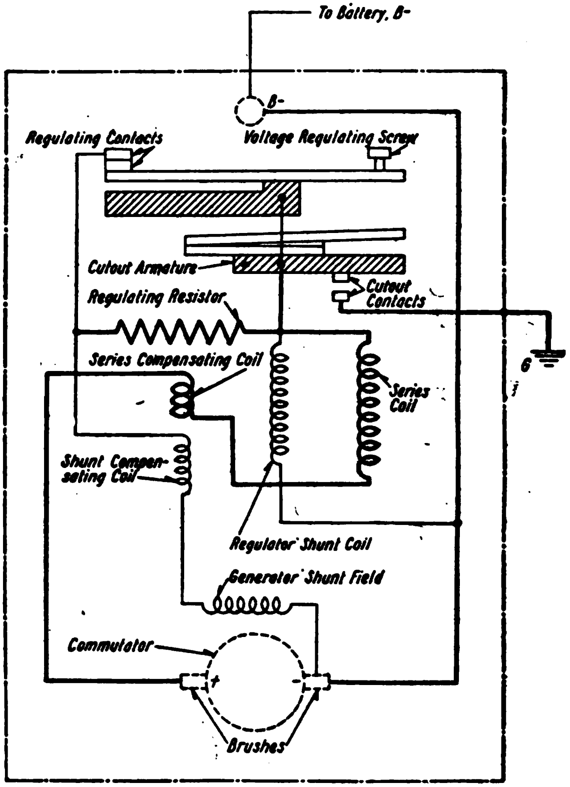


Figure 116.—Connections of Westinghouse Dynamo with Self-Contained Voltage Regulator and Cut-Out.

being meshed crank the engine with the full current allowed by the second switch position.

NORTH EAST

North East equipment consists of a motor-dynamo operating as a motor at twelve, sixteen or twenty-four volts and as a dynamo at six, eight or twelve volts. These machines carry a single armature and set of brushes and have compound wound fields. While some of the earlier models were connected to the engine through reduction gearing, a majority of these equipments are direct-connected and operate at a constant ratio of speed through silent chains or gears.

The dynamo housing encloses an electromagnetic cut-out and a vibrating regulator that acts to limit the amperage of the machine as a dynamo. Either the single or double-wire system is used.

U. S. L.

All of the systems furnished by the United States Light and Heating Corporation include a large size motor-dynamo mounted directly on the engine crankshaft. The starting voltage may be either twelve or twenty-four, while lighting and charging is cared for at either six or twelve volts. Electromagnetic cut-outs have been used on all types and in the earlier models the cut-out is combined with an amperage regulator consisting of a series of carbon discs whose pressure on each other is controlled by the tension of a coiled spring which is allowed to increase or decrease through the opposing strength of an electromagnet in series with the charging lines. Later models of this make of apparatus control the output of the electric machine as a dynamo by means of field coils which either assist or oppose the shunt windings according to the speed and output of the machine, Figure 117.

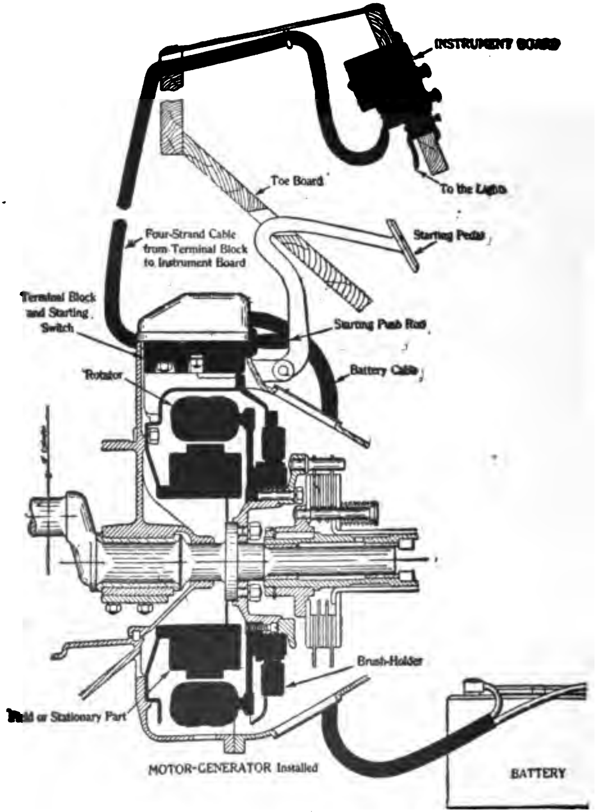


Figure 117.—U. S. L. Motor-Dynamo on Engine Crankshaft.

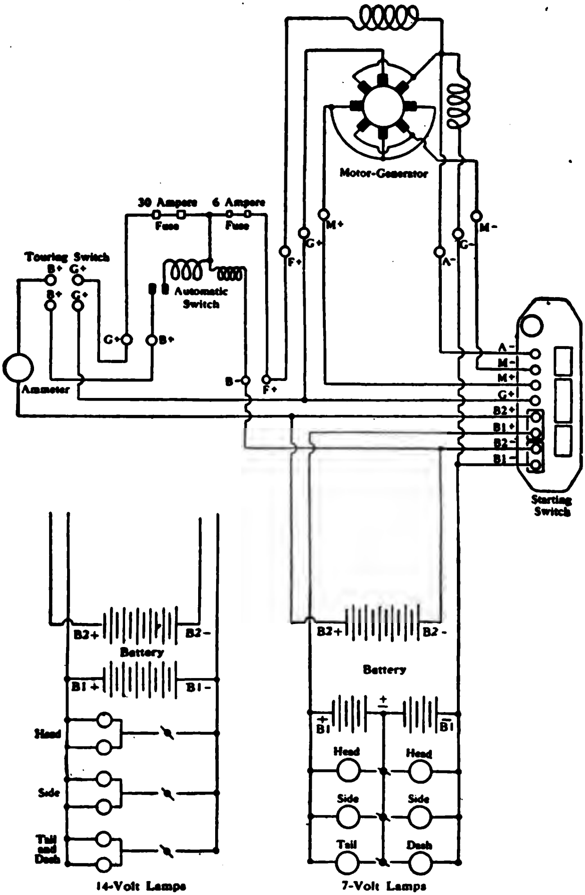


Figure 118.—Wiring for U. S. L. System Having Inherent Regulation.

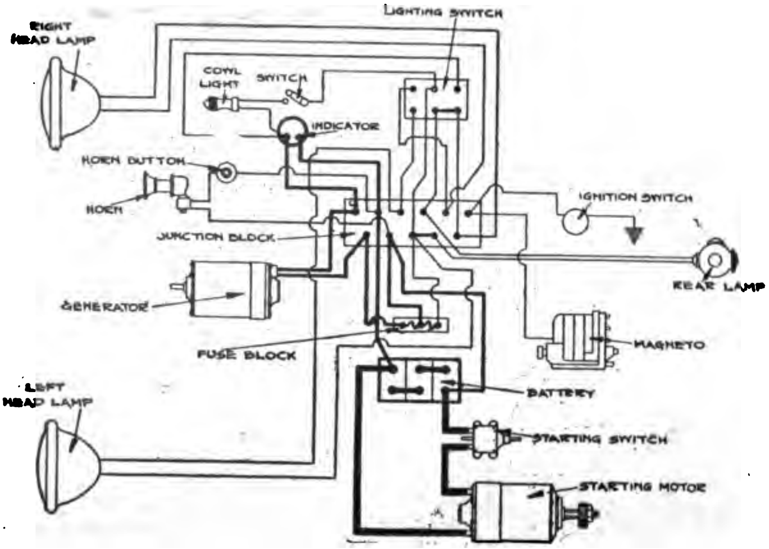


Figure 119.—Typical Wiring for Bijur System with Third-Brush Dynamo.

With the types that start at a high voltage, and use a lower pressure for charging and lighting, a form of commutating switch has been used which operates in an oil bath. Wiring for charging and starting may be on either the one or two-wire system, while lighting circuits may be of the one, two or three-wire type. See Figure 118.

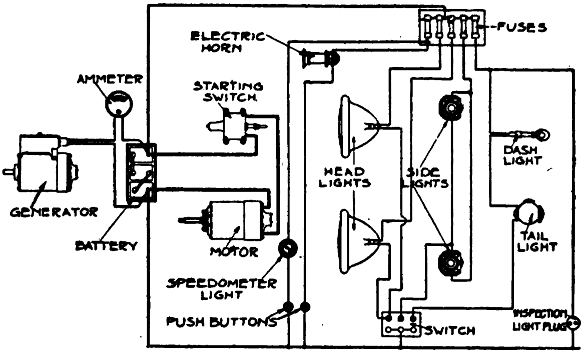


Figure 120.—Wiring for Bijur System with Constant Voltage Regulator.

BIJUR

Two types of dynamos and a motor-dynamo have been marketed. Both of the separate dynamos are of the shunt wound type, one operating on the third-brush principle, Figure 119, and the other being a constant voltage machine, Figure 120, controlled by the action of a vibrating regulator for the field resistance combined with an electromagnetic cut-out in a housing attached to the top of the dynamo. The third-brush dynamo is fitted with an electromagnetic cut-out carried inside of the dynamo case. Separate starting motors are of the series wound type and all of the separate unit apparatus operates at six volts.

The motor-dynamo is a twelve-volt machine having direct connection with the engine through a silent chain. The output control is by third-brush action for the shunt field current and the electric machine is connected to the battery through a hand-operated switch without the use of an electromagnetic cut-out.

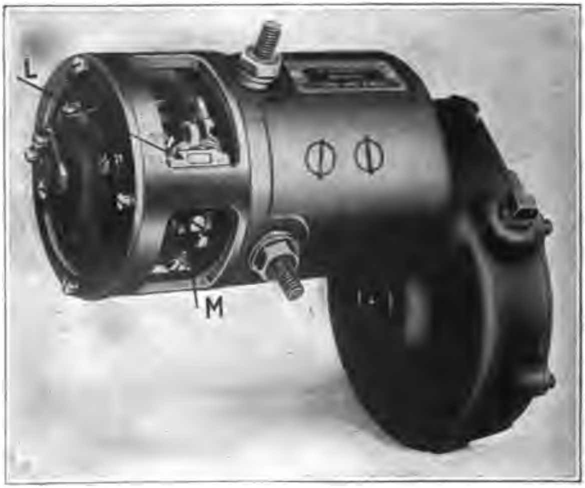


Figure 121.—Wagner Starting Motor. *L, M*—Brush Holders.

WAGNER

The first models of Wagner equipment include a motor-dynamo connected to the engine through a chain and planetary gearing. This machine acts as a starter at twelve volts pressure, and charges the battery at six volts. The commutating switch is mounted on top of the unit and is in the same housing with an electromagnetic cut-out. This machine is a compound wound unit with third-brush regulation for the shunt field current.

Later models of Wagner equipment make use of separate dynamos and motors, the dynamos being shunt wound with third-brush regulation, and the motors, Figure 121, being of the usual series wound form. The operating voltage for these separate unit installations may be either six or twelve. Wiring is either single or double throughout.

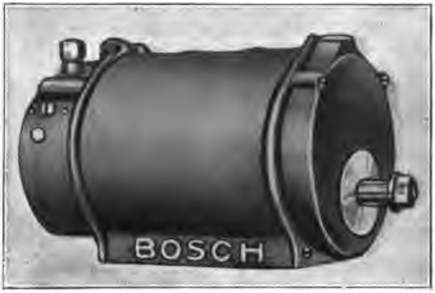


Figure 122.—Bosch Dynamo for Use with Voltage Control.

BOSCH AND RUSHMORE

The original Rushmore dynamo, and some of the newer models of Bosch dynamos make use of the iron wire controlled bucking field coil for regulation. Otherwise these machines are of the shunt wound type operating at either six or twelve volts and connected by either a double or single wire system. An electromagnetic cut-out is used in all cases, this unit being mounted on the dynamo or on a separate panel.

One type of Bosch dynamo, Figure 122, is a constant-voltage machine having a regulator whose resistance is composed of carbon particles and mica. This regulator is carried in a housing with the electromagnetic cut-out and a voltmeter. These machines are of the twelve-volt type.

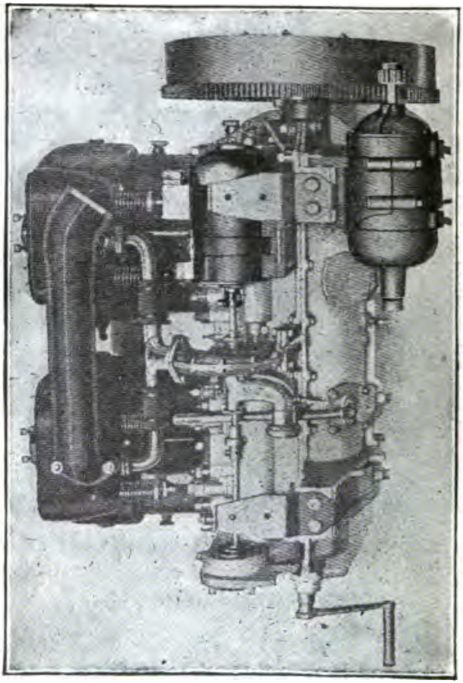


Figure 123.—Arrangement of Rushmore Units on Engine.

Rushmore type starting motors are used with any of the dynamos just described. This form of starting motor, Figure 123, causes the drive pinion to mesh with the flywheel gear by means of the end motion of the armature shaft induced through the pull of the field magnets, this action having been described in Chapter VI.

SPLITDORF

Splitdorf equipment includes a motor-dynamo, Figure 124, operating at twelve volts for both starting and charging or else at twelve volts for starting and six volts for charging. In any case the unit is direct-connected to the engine by means of a silent chain and operates at a constant ratio of speed with the engine.

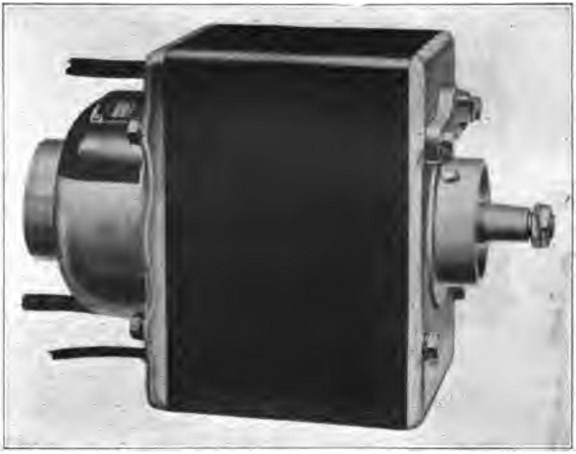


Figure 124.—Splitdorf-Apelco Motor-Dynamo.

The electric unit is compound wound and is connected to the battery by means of a separately mounted electromagnetic cut-out having a target arranged to show the words "OFF" or "ON" according to whether the cut-out is open or closed respectively.

The straight twelve-volt system makes use of a single-contact starting switch, while the six-twelve volt system uses a commutating switch to make the proper connections between battery sections and motor-dynamo. Either one or two-wire systems may be used, although the one-wire type is the one generally adopted.

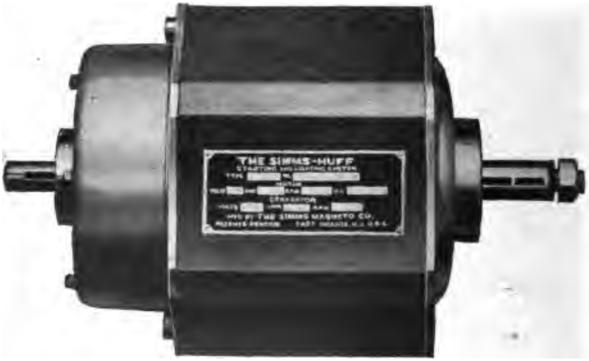


Figure 125.—Simms-Huff Motor-Dynamo.

SIMMS-HUFF

This equipment uses a compound wound motor-dynamo, Figure 125, driven as a dynamo from the engine through a flat belt and driving the engine as a starting motor through sliding gears. A two-section battery is connected with the electric machine at twelve volts for starting and six volts for charging, the necessary changes being accomplished with a commutating switch.

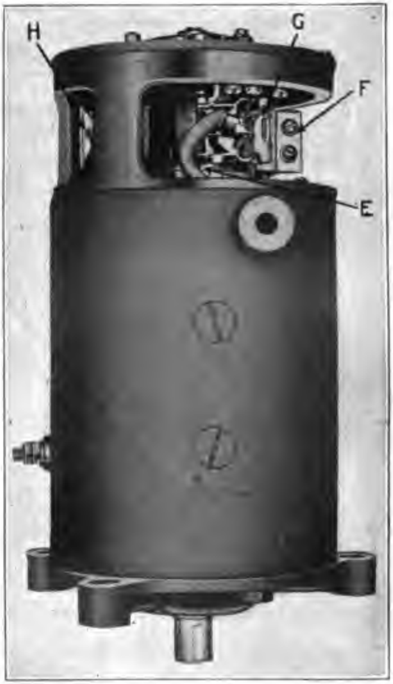


Figure 126.—Allis-Chalmers Motor-Dynamo.

E—Commutator. *F*—Brush Holder. *G, H*—Pig-Tails.

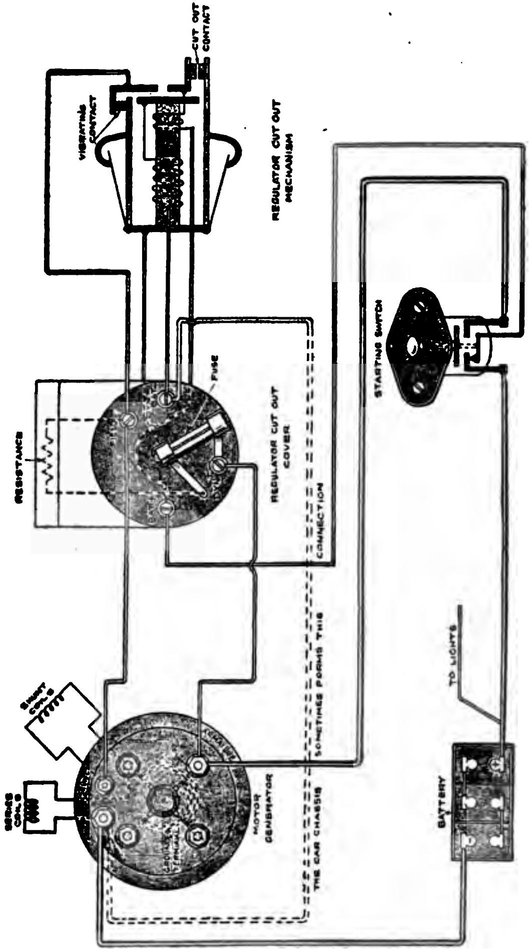


Figure 127.—Wiring for Allis-Chalmers Motor-Dynamo System.

An electromagnetic cut-out combined with a vibrating regulator acting to insert field resistance is employed to control the action of the machine as a dynamo. Further regulation is provided by the reversed series action of the series field winding while the unit is generating. The one-wire system with grounded return is used throughout the installation.

ALLIS-CHALMERS

The Allis-Chalmers equipments in general use consist of a compound wound motor-dynamo, Figure 126, operating at six volts under all conditions and directly connected with the engine so that it runs at a constant ratio of speed. The electric machine is connected with the battery for charging by means of an electromagnetic cut-out carried in the same housing with a vibrating regulator that inserts resistance in the shunt field when the correct amperage has been reached. All circuits are of the single wire type. See Figure 127.

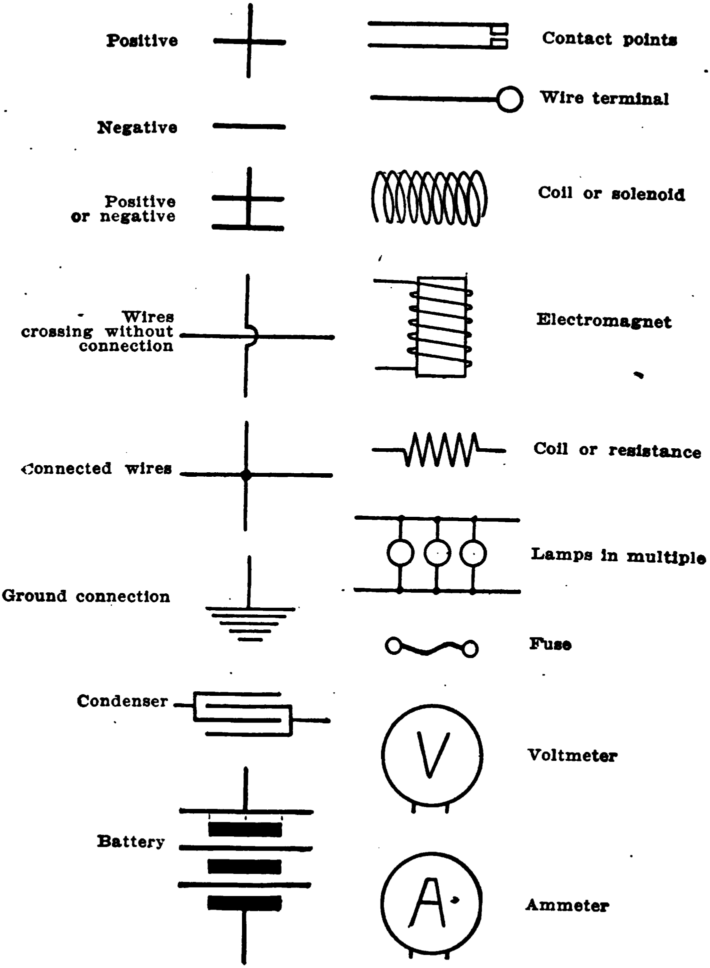


Figure 128.—Symbols Used in Wiring Diagrams.

CHAPTER IX

ELECTRICAL WORDS AND TERMS

A. C.—An abbreviation for alternating current. See *Current, Alternating.*

Accumulator.—A storage battery. See *Battery, Storage.*

Acid, Battery.—Chemically pure sulphuric acid having a specific gravity of about 1.835, suitable for use in making storage-battery electrolyte for lead cells.

Adapter.—A small threaded sleeve designed to screw into a candelabra base so that a miniature bulb may be used.

Ammeter.—An instrument for measuring the rate of flow of electric current directly in amperes.

Amperage, Constant.—Descriptive of a form of regulation which allows the dynamo current to rise rapidly to a predetermined maximum and then causes the dynamo to maintain this value of current without much rise or fall at all higher speeds.

Ampere.—The unit of current flow. Corresponds to gallons per minute in measurement of water flow. The rate of flow caused to pass through a circuit whose resistance is one ohm by an electrical pressure of one volt.

Ampere-Hour.—The quantity of electric current that flows during one hour through a circuit in which one ampere is passing. Equals 3,600 coulombs. Used in measuring the capacity of storage batteries, in which case a battery having a capacity of 80 ampere-hours would be capable of maintaining a flow of eight amperes for ten hours, ten amperes for eight hours, or any other combination of hours and amperes which multiplied together will result in eighty.

Ampere Turn.—One complete turn of a conductor in a coil through which one ampere is passing. The amperage multiplied by the number of turns in a coil gives the number of ampere-turns in that coil. The ampere turns of a coil determine its magnetic strength and the same strength will always be developed by the same number of ampere turns whether they result from a large number of turns and few amperes or large amperage and few turns.

Arc.—The flash or spark between two parts of a conducting path through which current is flowing when these parts are caused to separate. Seen at cut-out contacts, regulator contacts, dynamo and motor brush contacts on their commutators, etc.

Armature.—A piece of iron or steel so placed that it is in the field of a magnet or is acted upon by the lines of force of a magnet.

Armature, Dynamo or Motor.—A part of the machine which consists of an iron core on which is wound coils of wire. In the case of a dynamo, the movement of these coils through the magnetic field causes voltage to be generated and a flow of current to result. In the case of a motor the operating current, or part of it, is sent through the armature windings and the result, together with the effect of the fields, causes the reaction which results in delivery of power from the motor. The armature is usually the part of the machine that revolves, although in some dynamos the armature is stationary and the fields are revolved.

Armature, Drum.—A form of armature in which the windings pass from end to end of the iron core and around the ends. The core is usually a solid mass of iron of cylindrical shape.

Armature, Magnet.—A small piece of iron or steel mounted on a movable holder and carried near one end of an electromagnet. The armature is attracted to the magnet whenever current flows through the magnet windings. Attached to the movable arms of cut-outs, regulator vibrators, circuit breakers, etc.

Armature Reaction.—A term often used to describe the effect of the rotating armature core in carrying the lines of force of the field part way around in the direction of revolution while the dynamo is in operation. With stationary brushes the voltage between the points on the commutator against which the brushes bear will vary with the extent of this effect present. Utilized in "third brush regulation."

Armature, Ring.—Sometimes called a "Gramme" ring armature. An armature whose windings are placed around a circular or ring-shaped core.

Ballast Coil.—The length of iron wire inserted in the charging circuit of Rushmore and some Bosch-Rushmore dynamos which acts to send a part of the current around the bucking field coil with excessive increase of current generated.

Bar, Commutator.—See *Segment.*

Battery, Storage.—A number of storage cells placed together as a single unit and arranged to be connected with each other to give the desired voltage for the circuits to which the battery is attached.

Bayonet Base.—A form of lamp bulb socket of cylindrical form and hollow with two or more lengthwise slots open at the lamp end and ending in a turned over or hooked portion of the slot at the other end. The corresponding bulb base carries two or more projecting pins designed to slide down into the slots and then engage with the hooked portions by giving the bulb a part of a turn. The two parts are then held together by the pressure of small plungers or flat springs in the socket portion.

Bendix Drive.—A form of starting motor drive which causes a pinion carried on a threaded shaft attached to the armature shaft to revolve on this threaded shaft and because of its travel along the threads to mesh with teeth on the rim of the engine flywheel so that the power of the starting motor is applied to crank the engine.

Brush.—Pieces of some conducting substance, usually carbon composition or copper, which bear on a moving surface such as a commutator or the segments of a rheostat and which collect or distribute current.

Bucking Coil.—A winding placed on the field magnets of a dynamo and which opposes the strength of the shunt field winding whenever current is passed through the bucking coil. Used to obtain regulation of dynamo output.

Buckling.—An action that takes place in the plates of a storage cell which causes the entire plate to bend or warp.

Bulb.—The glass part of an incandescent lamp. Often used to designate the glass bulb with the filament and base.

Bus-Bar.—A strip of copper or brass which carries a number of terminals to which conductors and wires of an electric system may be attached.

Cable.—A conducting wire with its insulation. Usually applied to such wires when they are of comparatively large size.

Calibrate.—To determine the accuracy of the indications given by an electrical instrument such as a voltmeter or ammeter and to note the error, if any, between the scale divisions on the instrument being calibrated and another one of known accuracy or with currents and voltages of known value. Usually employed to designate the operation of correcting the working of an instrument so that its indications are correct.

Candelabra.—The name given to the larger of the two sizes of screw bases used for lamps employed in car lighting.

Candlepower.—The unit used in measuring the light given by any source of illumination. One candlepower is the light given by a standard candle made to burn a certain definite quantity of spermaceti each minute and of standard dimensions and construction.

Capacity, Battery.—The number of ampere-hours discharge that may be secured from a storage battery. It is affected by the rate of discharge in amperes, by the voltage, specific gravity and condition of the plates in the cells, by the temperature of the battery and by many other factors.

Carbon.—A chemical element. Found in graphite, charcoal, diamonds and fuel substances generally.

Cell, Storage.—A unit consisting of several positive plates and several negatives with plates of like polarity connected together and with the whole set immersed in a bath of electrolyte and enclosed by a jar of insulating material. A storage cell gives a voltage of approximately two, regardless of its size, but the capacity depends on the quantity of material in the plates and the design of the battery parts.

Charge.—The action of sending a flow of current through a storage battery so that a chemical change is caused to take place which results in the ability of the battery to deliver current.

Circuit.—The complete path through which a current flows from the time it leaves the source until it returns to the source. A circuit must always consist of three parts when employed in electrical equipment; namely, the source which may be the dynamo or the battery, the conductors which consist of wires and connections for both positive and negative sides, and the receptive or current-consuming devices which may consist of the lights, starting motor or other equipment. A circuit must always start with and end with the source, and if any portion of the circuit is incomplete there can be no flow of current at any point or in any part of the circuit.

Circuit Breaker.—A device consisting principally of electromagnets and current-carrying contacts which is designed to open a circuit whenever the current flowing through it exceeds a certain value. This name is often applied to a cut-out, although a circuit breaker and a cut-out do not perform similar duties.

Circuit, Closed.—A circuit that is complete from the source to the current-consuming devices and from these devices back to the source and through which a current can flow.

Circuit, Grounded.—A circuit which is completed through the metal work of the car. The metal work takes the place of any other conductor for a certain portion of the path.

Circuit, Open.—A conducting path which is not complete from the source of current to the current-consuming devices and back to the source. No current can flow through a circuit that is open at any point in its path.

Circuit, Short.—A connection between two wires or conductors of opposite polarity that allows the current flowing from the source to complete a path back to the source without going through the current-consuming devices or without doing the work that it should were the current forced to pass through the whole circuit. Should a current-carrying conductor of one polarity come into contact with the frame or metal work of the car when this metal work forms a part of the circuit of opposite polarity from the first conductor, a form of short circuit called a ''ground'' is formed.

Clips, Fuse.—The small spring or screw holders which carry a cartridge fuse.

Clutch, Overrunning.—A device consisting of two parts, one driven from the starting motor and the other driving to the engine to be cranked, with these parts arranged to be held together by wedging rollers when the starting motor drives the engine, but so arranged that the rollers will release and allow the engine to run free when its speed exceeds that at which the starting motor can drive it.

C. O. D. Indicator.—See *Indicator.*

Coil.—One turn or a number of turns of wire surrounding a central core usually of iron or wound on a support that allows a hollow space through the center of the coil.

Coil, Compensating.—The name applied to one of the windings on one of the field magnets in the U. S. L. motor-dynamo. The function of this winding is to control the dynamo output by assisting the shunt field at low speeds and by opposing the shunt at high speeds.

Commutator.—The series of segments attached to the armature windings of a direct current dynamo or motor and on which the brushes bear. The segments pass underneath the brushes at such a time that the alternating current produced in the armature windings is changed into a direct current for use in the outside circuits.

Compound Winding.—See *Winding, Compound.*

Condenser.—A number of sheets of some thin conductor, usually tin foil, placed one on top of another but separated by some insulating material such as mica or waxed paper. The sheets of conductor are connected in two sets, every alternate sheet being fastened to one lead and those between to the other lead. The condenser is placed so that one lead attaches to one current-breaking contact while the other lead attaches to the other contact. A part of the electricity that would ordinarily result in a spark at the time the contacts separate, passes into the condenser and remains there until the contacts again close, at which time this electricity from the condenser adds its effect to that passing through the contacts.

Conductor.—Any material or substance through which the electric current can pass with ease. All metals and many liquids are good conductors.

Conductivity.—The opposite of resistance. A measure of the readiness or ease with which current can pass through a conductor. The higher the resistance to passage of current becomes, the less will the conductivity become.

Conduit.—A tubular protecting covering for electric wiring generally made from metal and either flexible or rigid.

Connector.—A device for completing one or both sides of a circuit by means of pin plungers carried by one part of the connector and designed to fit into holes in the other part of the device. The ends of the circuit wires are fastened to the pin at one side and to the metal lining of the hole at the other.

Constant Amperage or Voltage.—See *Amperage, Constant,* and *Voltage. Constant.*

Contacts.—Small pieces of heat and spark-resisting conductor, usually metal or carbon, that carry the current flowing through a circuit when two of the contacts are touching each other and which act to break the circuit when they are drawn apart.

Control.—The action of limiting the current delivered from a dynamo and of preventing the current in the charging circuits from taking improper paths. Control is effected by the current regulating system and by the cut-out.

Controller.—An electromagnetic cut-out and a current output or voltage regulating device carried in one case or combined with each other so that some of their parts function with both units.

Core.—The iron form upon which coils of wire are carried or wound in forming electromagnets, dynamo or motor field magnets, armatures, etc.

Corrosion.—The action of acids or alkalies upon metal or the substance formed by this action. Found on the terminal connections of storage batteries and between the metal of their grids and the active material of the plates.

Coulomb.—A unit which measures electrical quantity and whose value is 1/3600 of an ampere-hour. A coulomb is the quantity of electricity that passes through a circuit in one second if the rate of flow is one ampere.

Current.—The rate of flow or the quantity of electricity that is passing through a circuit. Current flow is measured in amperes and is increased with increase of pressure or voltage and is decreased by increase of resistance.

Current, Alternating.—A current which reverses its direction of flow or its polarity at regular intervals. Alternating current is generated by all dynamos and in direct current dynamos the alternating current is changed to direct current by the commutator.

Current, Continuous.—Direct Current (which see).

Current, Direct.—A current which always flows in the same direction through its circuit and which would cause conductors through which it flows to remain of the same polarity at all times.

Current, Eddy.—Currents produced in the iron cores of the armature and field magnets of motors and dynamos by the motion of these parts in a magnetic field or by the motion of magnetic lines of force about them.

Current, Pulsating.—A current whose value rises and falls suddenly.

Cut-in.—The closing of the charging circuit by the cut-out when its contacts come together. Cut-in time means the engine or armature speed at which this action takes place.

Cut-out.—A switch through which the charging circuit from dynamo to battery is completed. When the cut-out is open there can be no flow through the charging circuit, either from dynamo to battery or from the battery through the dynamo. When the cut-out is closed a current may flow in either direction and the direction of flow will be from the unit having the higher voltage to the one of lower voltage.

Cut-out, Electromagnetic.—A cut-out switch whose current-carrying contacts are closed by the magnetic strength of an electromagnet through the windings of which current flows from the dynamo and whose strength is determined by the voltage generated by the dynamo. The contacts are opened and held open by the action of a spring or by the force of gravity which opposes the electromagnet.

Cut-out, Hand or Manual.—A cut-out switch operated by the driver of the car and so connected with either the ignition or starting switches that the cut-out will be open whenever the engine is idle or the ignition turned off and will be closed by the closing of the starting switch or by the closing or turning on of the ignition switch.

D. C.—Direct Current. See *Current, Direct.*

Discharge.—The flow of current from a storage battery to and through the outside circuits. Any flow which causes the capacity of the battery to decrease. Any flow whose direction is away from the positive terminals of the battery and into the negative.

Distribution Panel.—See *Panel, Distribution.*

Double Contact.—A name descriptive of a lamp bulb whose base carries two metallic points through which current enters and leaves the bulb. Also applied to a base designed to receive such a bulb.

Double Deck.—A motor and a dynamo which form separate units electrically but which are mechanically fastened together with one above the other either in one housing or in separate cases.

Double Wire.—See *Two-Wire System.*

Dynamo.—An electric machine which changes mechanical power into electric current.

Ediswan.—See *Bayonet.*

Efficiency.—The amount of useful work or power that may be taken from a device in proportion to the power or work of some other form that is consumed by the device while working. The efficiency of a storage battery is the percentage of ampere-hours' discharge that may be secured in comparison with the number of ampere-hours' charge that is given. The efficiency of a dynamo is the percentage of current that it delivers in proportion to the power it requires to drive the dynamo while delivering that current. The efficiency of an electric motor is the percentage of power delivered in proportion to the flow and pressure of electricity that the motor requires in order to deliver that power.

Electricity.—The name given to the cause of electrical effects of all kinds.

Electromagnet.—A magnet made from a core of soft iron and magnetized by the passage of a current of electricity through a coil of wire surrounding the core.

Electromotive Force.—Electrical pressure, potential or voltage. Ability to do work.

Energize.—In speaking of a coil or magnet this means that the coil or magnet receives current and produces magnetism.

Faure Plate.—A pasted plate for a storage battery. See *Plate, Pasted.*

Field.—The space around the poles of a magnet through which the magnetism or magnetic lines of force of the magnet will produce certain effects is called the field of the magnet. As the word is ordinarily used it means the field winding or the field winding and magnet core of a dynamo or motor.

Filament.—The conductor carried inside of the bulb of a lamp and which gives light when heated to incandescence by the passage of current against its resistance and through its length.

Finish Rate.—The number of amperes that may safely be passed through a storage battery for a period of from eight to twenty-four hours in completely charging the cells. Same as twenty-four rate. Depends on the ampere-hour capacity of the battery and is usually a number of amperes that corresponds to about one-twentieth of the ampere-hour capacity.

Floating.—Placing a battery in a lighting and starting system so that one side of the circuit includes and attaches to the positive terminal of the battery, of the dynamo, of the lamps and of the starting motor, and so that the other side of the circuit attaches to the negative terminals of these units. The battery may then receive current from the dynamo when the dynamo output is above the current required by the lamps, etc., and will give the required additional amount of current to the circuit whenever the dynamo output is less than the requirements of the current-consuming devices. The battery acts as a reservoir into which any excess current passes and from which any deficiency may be drawn.

Foot Pound.—See *Pound, Foot.*

Formed.—The condition of storage battery plates after the material in their plates has been changed to peroxide of lead for the positive and to sponge lead for the negative by the passage of a charging current and by intervening discharges sufficient in number and time to produce this effect.

Fuse.—A short length of wire of various compositions which is so proportioned and made that it will carry any amperage up to a certain predetermined maximum, but will heat to the melting point and separate when this current is exceeded, thus breaking the circuit protected by the fuse.

Fuse, Cartridge.—A fuse enclosed in a tube, generally made from fibre or glass and capped with metal at each end so that when placed in fuse clips the current may pass from the clips through the caps and through the fuse. Used when it is desired to avoid a spark in the open air.

Fuse, Field.—A fuse placed in the circuit of the field windings of a dynamo and of such a capacity that it will melt and open the field circuit when the amperage reaches a point beyond which there would be danger of burning out the field windings themselves.

Fuse, Link.—An unenclosed fuse wire.

Gap, Air.—The distance between the end or pole of a magnet and the iron of the magnet's armature which may be the iron of the dynamo or motor armature core or the armature piece of an electromagnet.

Gassing.—The evolution of hydrogen and oxygen gases from the water in the electrolyte of a storage cell caused by the passage of charging current through the cell.

Gear.—The larger one of two toothed wheels which are in mesh. The smaller one is called the pinion.

Gear, Helical.—A gear having its teeth of such form that they slant across the face. If such a gear were wide enough across the teeth or long enough in the direction of its hub and axis, the teeth would form complete turns around it.

Generator.—A name sometimes applied to a dynamo.

Gramme Ring Armature.—See *Armature, Ring.*

Gravity.—See *Specific Gravity.*

Grid.—The metallic framework which supports the active material and which with the active material forms a plate of a storage cell.

Ground.—The name applied to the metal parts of a car. The "ground" or metal is used to complete one side of the circuits in a one-wire system. Whenever a conductor or an electrical device is in metallic and electrical connection with the metal parts of the car the conductor or device is said to be "grounded" to the part on which it attaches or is mounted. See also, Circuit, Grounded and Circuit, Short.

Ground Return.—A name applied to a one-wire system or a system in which a part of either the positive or negative side of some or all of the circuits is completed through the metal work of the car.

Holder, Brush.—The part of a dynamo, motor, rheostat, etc., to which the brushes are fastened or in which the brushes are carried. The holder may be rigidly mounted or may be carried on pivot bearings.

Horsepower.—The rate at which work is done when 33,000 pounds is raised to a height of one foot in one minute. Provided this amount of work has been done in one minute one horsepower is being expended. To do the same amount of work in one-half the time would require twice the mechanical power or two horsepower of effort although the total amount of work done would remain the same. An electrical horsepower equals 746 watts. The horsepower that a current is capable of developing may be found by multiplying the number of volts by the number of amperes to find the number of watts and then by dividing this number of watts by 746, which will give the number of horsepower or the fraction of one horsepower.

Hydrometer.—A device for finding the weight of a liquid in relation to the weight of water. The usual form of hydrometer consists of a glass tube weighted at the lower end, having an air bulb above the weight and carrying a thin extension or tube above the air bulb. The hydrometer will sink into any liquid to a point on the extended tube or stem that corresponds to the weight of that liquid. The stem is graduated according to the specific gravity scale which assumes water to be unity and represented by 1.000. A liquid twice as heavy as water would then have a specific gravity of 2.000, etc. The point on the scale carried by the stem to which the hydrometer sinks indicates the weight or specific gravity of the liquid in which it is floating. See *Specific Gravity.*

Hydrometer Syringe.—A glass tube containing a hydrometer and into which a liquid to be tested may be drawn through a nozzle at the lower end of the tube. The upper end of the tube carries a rubber bulb which may be compressed to afford the suction necessary in drawing liquid into the tube.

Ignition-Dynamo.—A dynamo which carries an ignition breaker and distributor driven from the dynamo shaft and designed to make use of current from the dynamo or the storage battery charged from the dynamo.

Indicator.—A device which indicates flow of current through a circuit in which it is placed and shows in which direction the current is traveling. Some indicators have a hand like an ammeter, this hand swinging to words such as "Charge" when the battery is receiving current, "Off" when there is no flow into or out of the battery, and "Discharge" when current flows from the battery. In some forms the words themselves move into view according to the conditions existing. These instruments are often called "C. O. D. Indicators."

Induction.—The production of electrical pressure in conductors which are moved into and out of a magnetic field or which are allowed to remain stationary while a magnetic field in which they lie alternately increases and decreases. Induction is brought about when conductors move through lines of force or when lines of force move across a conductor. The current that is caused to flow in the conductor by the pressure is often called an induced current.

Inertia Pinion.—A starting motor drive operating on the same principle as the Bendix Drive, which see.

Inherent.—Some effect in a machine that is a natural result of the design and construction used in the machine and that does not require the use of external or additional moving parts to accomplish the result. Used to describe certain forms of regulation, especially reversed series systems in which it is the direction of winding the series coil that produces the inherent regulation.

Insulated Return.—A name applied to a one-wire system, which see.

Insulation.—Material that is a non-conductor of electricity and that is used in connection with conductors to prevent current passing from the conductor at any point where such passage is not desired.

Iron Wire Control.—A system of regulation used with Rushmore and some Bosch-Rushmore dynamos by which a length of iron wire is made to send current through a bucking field coil by the heating of the iron with passage of excessive current through it.

Jar, Battery.—A receptacle made from a material that will carry liquids without leakage and which is an electrical insulator. The plates and electrolyte of storage cells are placed in the jar.

Junction.—A terminal connection, often enclosed, at which a circuit divides into two or more parts.

Keeper, Magnet.—A small piece of iron or steel placed across the poles or ends of a permanent magnet and affording a path through which the magnetic circuit may be completed.

Kilowatt.—One thousand watts. Approximately 1⅓ horsepower.

Lead, Peroxide of.—The chemical substance formed by the combination of one part of metallic lead with two parts of oxygen.

Lead, Sponge.—Pure metallic lead of a porous or spongy form.

Lead, Sulphate of.—The chemical substance formed by the combination of one part of metallic lead with one part of sulphur and four parts of oxygen.

Lines of Force.—The paths taken by the magnetism around the poles and in the fields of magnets.

Load.—The resistance placed in a circuit and through which current passing in that circuit must flow. The load may take the form of lamps, starting motor or any other current-consuming device.

Magnet.—A material possessing the power of attracting other magnetic bodies or iron and steel. A material having a field of magnetic lines of force. For practical purposes magnets may be made only from iron or steel.

Magnet, Compound.—Two or more single magnets placed together so that their like poles are side by side.

Magnet, Electro.—See *Electromagnet.*

Magnet, Permanent.—A magnet made from hard steel and which remains magnetic for long periods of time under ordinary conditions of use.

Magnetic Lines of Force.—See *Lines of Force.*

Magnetism.—The condition of a magnetic material or a coil when they are surrounded by a field of magnetic lines of force.

Magnetism, Residual.—A slight magnetism that remains in any piece of iron or steel after it has been once magnetized.

Manual Cut-out.—See *Cut-out, Hand or Manual.*

Marker Bulb.—A small bulb carried by one of the large lamps of a car but outside of the focal point of the reflector. Also called pilot or dimmer bulbs.

Material, Active.—The paste formed from compounds of lead mixed with dilute sulphuric acid which is used to fill the grids of storage cells in making plates.

Mercury Well.—A voltage regulator used with some types of Delco equipment in which a resistance in the field circuit is more or less short-circuited by a bath of mercury.

Meter, Ampere-Hour.—A device that measures and indicates the quantity of electric current passing into or out of the storage battery. Used in connection with the regulating system of some Delco equipments.

Miniature.—The smallest size of screw base for incandescent lamps.

Motor.—An electric machine that changes electric current into mechanical power.

Motor-Dynamo.—An electric machine having one armature core with either one or two windings; one or two commutators and one set of field cores with two or more windings, which acts either as a dynamo or motor, according to whether it is supplied with power or electric current.

Multiple.—A form of circuit in which two or more sources of current or two or more current-consuming devices have their positive terminals connected together and their negatives connected together.

Negative.—See *Polarity.*

Neutral Wire.—A wire connected to each of two sources of current, either batteries or dynamos, so that current may flow in either direction through the wire according to which one of the two sources is being drawn upon for the greater amount of current. When the load is evenly divided between each source the neutral wire carries no current.

Nitrogen Bulb.—An incandescent lamp bulb in which the air has been replaced by the gas nitrogen.

Ohm.—The unit of the resistance to the passage of electricity. An ohm is the resistance that will allow one ampere of current to flow in a circuit when the pressure is one volt.

Ohm's Law.—The relation between electrical pressure, current flow and resistance is expressed by Ohm's Law as follows: The current or amperage equals the voltage divided by the resistance in ohms; the voltage equals the amperes of current multiplied by the resistance in ohms; the resistance may be found in ohms by dividing the voltage by the current in amperes. When *C* represents amperes, *E* represents volts and *R* represents ohms, the law may be expressed by the equations:

$$C = \frac{E}{R} \qquad E = C \times R \qquad R = \frac{E}{C}$$

One-Unit System.—An electric starting, lighting and ignition installation in which an ignition breaker and distributor is combined with a motor-dynamo thus allowing one unit to perform the three functions of lighting, starting and ignition.

One-Wire System.—A method of connection in which one side, either positive or negative, of all or part of the electrical devices and conductors is attached to the metal or ground of the car and in which the metal is used as a conductor to complete these circuits.

Open.—See *Circuit, Open.*

Output.—The number of amperes or the number of watts furnished by an electrical source such as a dynamo or battery.

Overrunning Clutch.—See *Clutch, Overrunning.*

Panel, Distribution.—A body or plate of insulating material to which lead the conductors for several circuits and which carries suitable terminal connections and suitable internal and external wiring to allow the circuits to be completed in their proper paths. Used to centralize the wiring and connections of the electrical system.

Parabolic Reflector.—A reflector whose surface is so shaped that a section cutting from side to side and through the center would form a parabola. This form causes the light reflected from a source of illumination placed in the fucus of the parabola to be thrown in parallel rays and straight ahead in the direction of the axis of the parabola.

Parallel.—See *Multiple.*

Paste, Battery Plate.—The filling for the grids of storage cell plates. See *Material, Active.*

Peroxide of Lead.—See *Lead, Peroxide of.*

Pig-Tail.—A short flexible wire that forms the electrical connection between a brush and the conductor that carries current to or from the brush.

Pilot Lamp.—A lamp placed in a charging circuit in such a way that it lights when the cut-out closes and remains lighted while the cut-out remains closed. Also used to designate a Marker Bulb, which see.

Pinion.—The smaller of two toothed wheels which are in mesh. The larger one is called the gear.

Plate, Battery.—One of the units entering into a storage battery cell. The plate is formed of a metal framework or grid whose spaces are filled with active material formed from a paste of compounds of lead mixed with dilute sulphuric acid. After forming, the material of the positive plate is peroxide of lead and that of the negative plate is sponge lead.

Plate, Pasted.—A plate conforming to the foregoing definition of Battery Plate as distinguished from plates formed from pure metallic lead which has been acted upon by the passage of charging current to change the surfaces into peroxide of lead and sponge lead for the positive and negative respectively. Sometimes called a Faure plate from the name of its inventor.

Plug, Vent.—A small screw or clamping plug placed in the opening of each cell of a battery and by means of openings in which the gases evolved during charging may escape.

Point.—One-thousandth of a specific gravity unit or 0.001. The difference between a specific gravity of 1.251 and 1.252 is one point, between 1.250 and 1.275 is twenty-five points, etc.

Polarity.—The direction in which electrical pressure tends to cause movement of a current determines the polarity. It is assumed that the earth forms a reservoir of electricity which does not tend to flow. When current flows to the earth the polarity of the conductor through which it passes and the earth end of the conductor is said to be positive. When current flows from the earth to a conductor and through the conductor the end of the conductor at which the current enters and the conductor itself is said to be of negative polarity. Current having positive polarity will flow in one direction and will pass to a conductor of negative polarity, while current from a negative conductor will not flow to one of positive polarity.

Should a positive conductor having a pressure of eight volts be attached to the end of another positive having a pressure of only six volts, the first will be positive to the second while the second, which was called positive, will become negative to the first conductor. Had the conductor with six volts pressure been connected to another having only four volts, the six-volt line would be positive to the four-volt, and the four-volt line would become negative to the six-volt. In this case the conductor having the higher voltage or pressure will be positive while the one of lower voltage will be negative.

In the case of a source of electricity, the terminal or end from which current is supposed to flow is called the positive terminal, while the terminal into which current flows is called the negative. Current flow is always from positive to negative and from a higher voltage to a lower.

Wires attached to a positive terminal are called positive wires until they reach the current-consuming device or the outer end of the circuit. Wires from the consuming-device to the source and attaching to the negative terminal at the source are called negative wires.

Magnetic polarity is used to distinguish the ends or poles of a magnet and is determined according to the direction of movement of the magnetic lines of force. The pole from which the lines of force leave the body of the magnet is called the positive or North pole and is designated by a plus sign, +. The pole at which the lines of force reenter the body of the magnet is called the negative or South pole and is designated by the minus sign, —.

Pole, Dynamo or Motor.—The ends of the field magnet cores that are presented to the armature and which form the walls of the armature tunnel. An electric machine having two field magnet cores is called a two-pole machine, one with four magnet cores or fields is called a four-pole machine, and so on, for any number.

Pole, Consequent.—A magnet pole formed when two ends of the same polarity, either positive or negative, are placed together, or a pole formed when two windings act to produce like poles at some point in a piece of iron located between the windings. In the case of a dynamo or motor the iron at the consequent pole is shaped to form a part of the armature tunnel but carries no windings.

Pole Piece.—A piece of iron or mild steel fastened to the end of a field magnet core and so shaped on its armature side as to form the curve of the armature tunnel.

Positive.—See *Polarity.*

Potential.—A term having the same meaning as voltage or electromotive force. The difference of electrical pressure between two points is their difference in potential. Potential is measured in volts.

Pound, Foot.—The work required to raise a weight of one pound to a height of one foot.

Pressure, Electrical.—The force that acts to send current through a circuit against the resistance of the circuit. Also called Potential and Electromotive Force. Measured in Volts.

Primary.—The winding of a transformer or ignition coil that receives the current from the battery or dynamo at low voltage and through the action of which on a magnetic core is produced the current of high voltage used for ignition. The wiring of the ignition circuits through which current of low voltage passes is called the primary wiring. A primary cell or battery is one which produces electric current by chemical action and in which this action can not be reversed as it can be in the storage cell.

Rectifier.—A device which changes an alternating current to a direct current.

Regulation.—The action of limiting or controlling the amperage, or voltage, or both amperage and voltage, of a dynamo.

Relay.—A device which closes or opens a circuit when the voltage or amperage rises to a certain value in a second circuit. A relay consists of an electromagnet through whose windings flows the current that controls the action of the relay and the time at which it will close a circuit, or open a circuit depending on its construction. When the relay is designed to close a circuit the armature of its magnet brings a movable contact to a stationary one and the circuit to be closed is completed through these contacts. When the relay is designed to open a circuit the movable and stationary contacts are so placed in relation to each other that movement of the relay magnet armature draws the contacts apart and opens a circuit that has been completed through the contacts. The word relay is often used to designate a cut-out or a regulator when these devices are electromagnetically operated.

Reversed Series.—A series winding placed on the field magnets of a dynamo and through which all of the current flowing from the dynamo passes in such a direction that the magnetic effect produced opposes the effect of the shunt field winding.

Rheostat.—A resistance or a number of resistances in series with each other whose effect in a circuit may be readily varied by changing the length or proportion of the resistance inserted in the circuit.

Section, Battery.—A part of a complete battery consisting of a number of cells arranged permanently in series with each other and having one positive and one negative terminal through which the section or series of cells may be connected with the outside circuits or with other sections of the battery in either a series or multiple circuit.

Segment.—A contact piece against which the brush of a motor, a dynamo or a rheostat bears and to which is attached one or more wires from the windings or resistances of these units.

Separator.—A sheet of insulating material, usually formed from specially prepared wood or hard rubber, which is used between adjoining plates in a storage cell so that these plates may not come into electrical connection with each other except at their lugs.

Series.—A connection of conductors made between several sources of current or between several current consuming devices in such a way that all of the current that passes through any one unit or conductor will also have to pass through every other unit and conductor in the series circuit. In the case of units having terminals of definite polarity the positive of one will be connected with the negative of the next one in the circuit and the positive of this second unit with the negative of the third, etc. See also Winding, Series.

S. G.—An abbreviation for *Specific Gravity,* which see.

Short.—See *Circuit, Short.*

Shunt.—A path of a circuit through which only a part of the whole current flows, the balance passing through one or more additional paths whose ends attach to the same source. When two conductors or two current-carrying devices are attached to a source of current so that there is a direct metallic path from each conductor or each device to each terminal, positive and negative, of the source, each part is called a shunt of the other one and the circuit from the source through either path and back to the source is said to be a shunt circuit. Any circuit in which part of the current may take one path while other parts take other paths consists of or contains shunts. Mutiple and parallel connections are forms of shunt circuits. See also *Winding, Shunt.*

Single-Contact.—A name descriptive of a lamp bulb whose base carries but one metallic point through which current may enter or leave the filament, the other side of the circuit being completed through the shell of the base. Also applied to a lamp base designed to receive such a bulb.

Single-Unit System.—See *One-Unit System.*

Single-Wire System.—See *One-Wire System.*

Solenoid.—A coil of wire without a metallic core, but through which a current may pass and which will produce magnetic effects and a magnetic field when a current does pass.

Specific Gravity.—A measure of the weight of a liquid which is expressed in decimal fractions or multiples of the weight of an equal volume of pure water. The specific gravity of water is assumed as unity or 1.000. Any liquid one-half as heavy as water will then have a specific gravity of 0.500, while a liquid twice as heavy will have a specific gravity of 2.000 and one, one and one-half times as heavy will have a specific gravity of 1.500. See also Hydrometer.

Speed, Critical.—The speed of a car in miles per hour, of a dynamo armature in revolutions per minute, etc., at which some certain action will take place in some part of the electrical equipment. The speed at which a cut-out will open or close, at which a motor-dynamo will maintain a voltage equal to that of the battery without charge or discharge and at which a speed regulator will act are all critical speeds for those particular actions.

Sponge Lead.—See *Lead, Sponge.*

Start Rate.—In battery charging, the rate of flow or amperage which may be passed through the battery for the first hour of charge from a separate source, or the maximum rate that may be safely maintained by the dynamo on the car.

Stop Charge.—Descriptive of any device, such as a relay, that acts to open the field circuit or perform some other action that will result in stopping the flow of current from the dynamo.

Storage Battery.—See *Battery, Storage.*

Sulphate of Lead.—See *Lead, Sulphate of.*

Sulphated.—The condition of a storage battery plate when its surface has become covered with a thick formation of crystals of lead sulphate which prevent normal charge and discharge of the cells affected.

Sulphuric Acid.—The acid used in making storage battery electrolyte. It is composed of two parts of hydrogen, one of sulphur and four of oxygen and is a heavy oily liquid which will rapidly corrode and eat away most materials and will produce severe burns on the flesh. It has a specific gravity of 1.835 for the kind usually employed in battery work. For such use this acid must be chemically pure, commercial acid not being suitable. Its action on the flesh or clothing may be stopped by the free and immediate application of strong ammonia water.

Switch, Commutating.—A form of switch connected to a battery composed of several sections and which places the sections in series with each other to produce a high voltage for starting while it connects them in multiple for charging and lighting.

Tandem.—A mechanical connection of two electric machines such as a dynamo and motor, a dynamo and magneto, etc., so that one shaft drives them both by passing through one unit and extending to the drive end of the other.

Tapering Charge.—A storage battery charge that decreases in amperage in direct proportion to the rise of voltage of the battery cells. A tapering charge is given by a dynamo whose voltage remains constant because the difference of voltage between dynamo and battery will be great at the beginning of the charge when the battery voltage is low, and will become less and less as the voltage of the battery more nearly approaches that of the dynamo as charging progresses.

Target.—A visible indicator or marker attached to the moving part of a cut-out or to the armature of a magnet whose winding forms part of the charging circuit. The marker will move into view when the cut-out closes or when current flows through the charging circuit.

Three-Unit System.—An electrical installation in which the starting motor, the dynamo and the ignition device are all separate and distinct units with no parts in common.

Three-Wire System.—A form of connection or circuit used for lighting with which two sets of lamps having different voltages may be operated from one battery or by means of which two sets of lamps are attached to two sections of a battery by means of three wires in place of four, the neutral wire acting for either set and being attached to both sections of the battery.

Third Brush.—A brush bearing on the commutator of a dynamo at a point somewhat distant from one of the main brushes and through which current flows to one end of the shunt field winding. The position of the third brush on the commutator determines the amount of current flowing through the field and the voltage acting at this brush varies in such a way that a rise followed by a fall of voltage and current is obtained with constantly increasing armature speed. Forms a method of regulation.

Torque.—The rotative or twisting power exerted by a shaft.

Touring Switch.—A switch placed in the charging or field circuit or in both of these circuits so that when the switch is opened the charge to the battery will be stopped as may be desirable with a fully charged battery.

Transformer Coil.—A magnetic core around which are wound two separate coils having different lengths and sizes of wire in each coil. Passage of a current which is pulsating or alternating, or alternate flow and stoppage of a current through one of the coils will produce an induced current in the other. If the exciting or primary current flows through the coil having fewer turns the secondary current from the other coil will be of higher voltage and less amperage, while flow of the primary current through the coil having a larger number of turns will induce a current of lower voltage and greater amperage in the other coil.

Tunnel, Armature.—The cylindrical passage formed between the ends or pole pieces of the field magnets of a dynamo or motor and in which the armature is placed.

Twenty-four Hour Rate.—See *Finish Rate.*

Two-Unit System.—An electric starting, lighting and ignition installation in which two of the units are combined with each other, the third being entirely separate, thus forming two principal parts. Such a system may use a motor-dynamo with separate ignition device, or an ignition-dynamo with separate starting motor.

Two-Wire System.—An electrical installation in which both sides of all circuits are completed through insulated conductors and in which no part of any circuit is carried by the metal of the car.

Under Cut.—To cut away a part of the insulation between commutator segments so that the surface of the segments is above that of the insulation by about $\frac{1}{32}$ inch.

Vacuum Bulb.—An incandescent lamp bulb from which almost all of the air has been exhausted and has not been replaced with any other gas.

Vibrator.—An electromagnet together with its armature and contact points used as a part of a regulator and so designed and connected that the armature and movable contact point vibrate at a high rate of speed so that the circuit completed through the contacts is rapidly opened and closed.

Volt.—The unit of electrical pressure, potential or electromotive force. One volt pressure is produced in a conductor that cuts or is passed through by one hundred million lines of magnetic force per second. One volt pressure will cause a flow of one ampere through a circuit whose resistance is one ohm.

Voltage.—The electrical pressure existing between two points.

Voltage, Constant.—Descriptive of a form of regulation that allows the dynamo voltage at the dynamo terminals to rise to a predetermined maximum and then causes this voltage to be maintained without any great rise or fall at all higher speeds of the dynamo.

Voltammeter.—A single measuring instrument that may be used either as an ammeter or a voltmeter. Also an instrument consisting of a voltmeter and a separate ammeter in one case.

Voltmeter.—An instrument that measures difference in electrical pressure between two points and which indicates this difference directly in volts on a suitable scale.

Watt.—The unit of electrical power. The power delivered by a circuit through which one ampere flows at a pressure of one volt. The number of watts may be found by multiplying the number of volts by the number of amperes of a circuit. One watt is equal to 1/746th of a mechanical horsepower. One watt is the power that must be developed to do 44¼ foot-pounds of work per minute.

Watt-Hour.—A unit of electrical work equal to a power of one watt used or applied for one hour.

Winding.—A coil composed of one or a number of turns of a conductor around a magnetic core.

Winding, Compound.—A form of dynamo or motor field winding consisting of a shunt and a series winding wound on the same or separate magnet cores and acting on one armature.

Winding, Series.—In a dynamo or motor, a field winding through which passes all of the current that flows through the armature and brushes and in which the armature windings and field windings are in a series circuit with each other. In a cut-out, controller or regular magnet, the winding or part of the winding through which all of the charging current passes.

Winding, Shunt.—In a dynamo or motor-dynamo, a field winding placed in shunt with the armature windings and with the outside circuits and through which only a part of the current that is generated in the armature or that is received from an outside source will flow. The shunt field winding is made of much higher resistance than the outside circuits so that no more than the necessary amount of current required to magnetize the field magnets will pass through the winding. In a cut-out, controller or regulator magnet, the winding that is connected to the positive side of the dynamo at one end and to the negative terminal of the dynamo at its other end which is always acted upon by the difference in pressure or voltage between the dynamo brushes.

Zero Center.—Descriptive of an electrical measuring instrument such as a voltmeter or ammeter in which the indicating pointer may travel from the zero point toward either end of the scale, both sides being graduated and having the zero point at the center of the scale or nearer to one side than to the other so that a reading of greater value may be obtained with current flowing in one direction than with it flowing in the other. The latter class of instruments is not properly named "zero center" but should be designated by the maximum readings each way, thus "10-0-30" meaning an instrument that will read to ten amperes or volts one way and to thirty amperes or volts in the other direction.

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